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Airfoil Design With Tangential Suction or Injection

927F0210B Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 8-11

[Article by Ye.Yu. Aristova, A.V. Potashev; UDC 532.5+517.54]

[Abstract] The importance of maximizing the airfoil lift-to-drag ratio and approaches to designing airfoils with suction/injection devices for this purpose are discussed and an approach based on solving the inverse problem whereby not the airfoil shape but the velocity distribution on it is the initial premise is considered. This approach is characterized in that the velocity distribution in the arc abscissa $v(s)$ fully determines both the lift and the boundary layer characteristics; thus, by assigning the $v(s)$ distribution and the suction/injection parameters we can ensure a continuum flow at high values of lift coefficient even before finding the airfoil shape. The problem is formulated and the requirements for the initial velocity distribution in the vicinity of the singular point are defined analytically. An airfoil with suction or injection is considered in the case where there is a slot in the contour with an outflow or source at its corner point, respectively. Examples of numerical realization of the problem solution on a computer are cited for a Zhukovskiy-type airfoil. Figures 4; references 5.

Feasibility of Simulating Gas Flow With Significant Parameter Gradients by Gas Hydraulic Analogy Method

927F0210C Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 12-17

[Article by Yu.M. Beletskiy, A.O. Ditman, V.D. Savchuk, I.R. Yakubov; UDC 530.17]

[Abstract] The feasibility of N.Ye. Zhukovskiy's gas-hydraulic analogy (GGA) method for simulating flows with various isoentropy indicators as the effect of vertical velocities and accelerations in a liquid flow is analyzed and the feasibility of using the gas-hydraulic analogy method for examining the gas flows with considerable flow parameter gradients is investigated. To this end, a three-dimensional nonstationary flow of an incompressible liquid with a free surface on a horizontal bottom is considered and the motion of the liquid is described by a system of continuity and momentum equations. Earlier assertions that the gas-hydraulic analogy method can be used for simulating only isoentropy gas process or flows with very weak shocks is refuted; the gas-hydraulic analogy between the gas flow with substantial parameter gradients and a "shallow" water flow with hydraulic jumps is substantiated theoretically and it is shown that the flow of a thin liquid layer with a free surface is indeed similar to the flow of a hypothetical gas with a specific heat ratio of $\gamma = 2$ on a plane. The hydraulic jumps appearing in the liquid flow are interpreted as blurred shock waves while vertical accelerations are regarded as changes in the entropy function of the gas. References 4.

Hydraulic Shock Analysis in Line With Damper at End

927F0210D Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 18-21

[Article by Yu.S. Mikheyev; UDC 532.595]

[Abstract] Equations of nonstationary movement of liquid in a long thin-walled elastic hydraulic line with a damper on the end is derived under the conditions that the flow be axisymmetric, the process be adiabatic, and the line straining be elastic are satisfied. The initial liquid flow conditions correspond to uniform rate and pressure along the entire line length. The expressions are based on the procedure described by N.M. Belyayev, N.P. Belik, et al in Reaktivnyye sistemy upravleniya kosmicheskikh letatelnykh apparatov (Moscow: Mashinostroyeniye, 1979). The efficacy of absorbing the hydraulic shock by dampers with an elastic element in the form of transverse corrugated bellows is investigated. The transient process in the hydraulic main are analyzed on a YeS-1051 computer for four types of hydraulic shock dampers—annular with cylindrical and rectilinear corrugated spacers, gas cap, with a curvilinear corrugated spacer, and hydroacoustic filter—with various elastic element designs. The damping degree of each type of damper and relevant patent numbers are summarized. Tables 1; references 3.

On-Line Analysis of Spatial Supersonic Flow Around Close-to-Axisymmetric Bodies

927F0210E Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 22-27

[Article by V.I. Timoshenko, V.P. Galinskiy; UDC 533.6.011]

[Abstract] The urgency of developing procedures for on-line aerodynamic analysis necessitated by the development of computer-aided aircraft design system and the need to find a compromise between the analysis accuracy and CPU time outlays in finding the distributed and total aerodynamic characteristics are stressed and one such procedure based on compiling a precise numerical solution of two-dimensional nonlinear and linearized three-dimensional gas dynamics equations is considered. The principal limitations of the method are summarized and ways of improving the calculation immediacy by using analytical approximations of gas dynamic functions of the meridional angle φ in the form of trigonometric polynomials are discussed. It is suggested that the system of equations be solved by the finite difference method of through calculation. To this end, a number of meridional planes is introduced to the

analysis domain; the capabilities of the proposed method are illustrated using the example of supersonic flow around a blunted 10°-cone, an axisymmetric body with generator breaks at $M = 3$ and 20 and an incidence angle of 1-10°, and a bielliptical body. The dependence of the normal force coefficient on the angle of incidence and the dependence of the computation time on the number of meridional planes and computation method are plotted. The advantage of the proposed procedure with circumferential derivative approximations over traditional finite difference methods is established. It is noted that the technique yields adequate results even in the case of asymmetric bodies. Figures 3; tables 2; references 7: 6 Russian, 1 Western.

Method of Assessing Gas Turbine Blade Cooling System Efficiency

927F0210F Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 27-30

[Article by M.I. Galkin, K.A. Malinovskiy, I.V. Shevchenko, M.S. Chernyy; UDC 629.7.036:621]

[Abstract] Traditional methods of estimating the efficiency of gas turbine blade cooling systems and their shortcomings due to the need to take into account the blade throughput characteristics and the problem of comparing the cooling efficiency for blades with different air rates and pressure drops are discussed and it is noted that the cooling efficiency and the heat flux density can be assessed more soundly as a function of the parameter which characterizes energy outlays for the pressure loss and thermal resistance during the air passage through the blade cavity being cooled, i.e., the work of pushing the cooling air through the blade's inner cavity. A formula of the energy variation function of the air passing through the cooled blade loop is derived and the experimental efficiency estimate function is reduced to a single expression. This generalized cooling efficiency representation makes it possible to compare the results obtained at various air rates through the blades and pressure drops and utilize experimental data available from other sources. Figures 3; references 5.

Plotting Universal Compressor Curve in Idling Conditions and Autorotation Mode

927F0210G Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 30-34

[Article by V.I. Dayneko; UDC 621.438]

[Abstract] The rotation speed limitations of universal axial-flow compressor performance curves in necessary for analyzing the idling and terminal operating modes of gas turbine engines and methods which make it possible to approximately estimate the behavior of the principal compressor operation parameters at low revolutions are discussed. Expressions are derived for plotting the universal compressor curve in the light duty mode and a more versatile formula is proposed which makes it possible to extend the curve not only to low RPM conditions but also to the autorotation mode. To this end, an experiment is conducted with a seven-stage axial-flow centrifugal compressor for the GTD-3F gas turbine engine. The proposed universal formula is not only suitable for plotting the compressor performance curve but is more versatile than known expressions and is recommended for analyzing the start-up and idling conditions of gas turbine engines, including autorotation. Figures 3; references 4.

Working Process Model and Investigation of Pulse Jet Engine Characteristics

927F0210H Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 34-38

[Article by P.P. Kostenko, D.A. Munshtukov, V.L. Simbirskiy, K.V. Belyakov; UDC 621.452]

[Abstract] The mathematical model of the pulse jet engine's working process—an extension of a model described in *Samoletostroyeniye: Tekhnika vozdushnogo flota*, Kharkov University, No 50 1983, pp. 37-44—is considered assuming that the real gas flow is unidimensional and the ideal gas equation of state is satisfied only locally while the mass, momentum, and energy sources and drains simulate the fuel combustion and energy dissipation in the setting. The working medium is modeled by a uniform mixture of pure stoichiometric combustion products and air. The method of flow singularities represented in the form of the above sources and sinks is used; the dependence of the thrust and pulse jet engine (VRD) cycle duration on the setting length, the pressure wave behavior in the pulse jet engine combustion chamber with an increase in the setting length, and the dependence of the thrust and cycle duration on the combustion process intensification factor are plotted. The findings may be used in designing pulse jet engines, intermittent action gas turbine plant combustion chambers, and pulsing heater burners. Figures 4; references 8: 4 Russian, 4 Western.

Porous System in Flame Jet Burners

927F0210I Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 39-43

[Article by V.M. Polyayev, A.A. Genbach; UDC 536.248.2]

[Abstract] A porous cooling system for the combustion chamber and jet-type supersonic nozzle burner designed for breaking up and treating concrete and its shortcomings, primarily the need to deliver water at a considerable pressure, are considered and a new capillary porous cooling system developed in its place by the authors is

described. The new system has high thermal parameters and is simple and reliable in use; in addition, it makes it possible to reduce the cooling water rate by several orders of magnitude and thus lessen the cooling system's environmental impact. A schematic diagram of the cooling system is cited and the effect of the heat flux on the wall overheating relative to the steam temperature at various cooling system orientations is plotted. An experimental study conducted with the burner and its prototype is described. The cooling surface used in the experiment is made from stainless steel 12N10T and 12Kh18N9T, L80 brass, M2 copper, nickel, alundum, and glass. The discrepancy between the experimental results and theoretical data on the heat inflow and the heat removal with the circulating and excess water does not exceed 12% while the material balance error does not exceed 10%. Figures 2; references 5.

Convective Heat Transfer on Cylindrical Surface in Gas Turbine Engine Rotor Cavities

927F0210J Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 43-48

[Article by N.N. Salov; UDC 621.438:536.24]

[Abstract] The importance of knowing the heat transfer and hydrodynamics of the annular cavities in gas turbine engine rotors for developing improved computer-aided heat control systems for the radial clearance and packing of compressor assemblies is stressed and the results of an experimental study of heat transfer from the cylindrical surface inside the annular rotating cavity to the coolant in the case of axial, radial, loop, and intermediate flow types through the cavity are presented. The study is aimed at finding the boundary value conditions of heat transfer for the spacer and labyrinth packing rotor rings of gas turbine engines. The experimental test bench used for measuring the mean heat transfer coefficients when the coolant is pumped through along the cavity rotation axis is described and the experimental findings are summarized on the basis of the similarity theory. A schematic diagram of the turbine setting is cited and the effect of the pumping rate on heat transfer in the cylindrical cavity, the effect of the outlet cross section area on the heat transfer, and the heat transfer efficiency of the cylindrical surface for various flow versions are plotted. The efficiency comparison demonstrates that an increase in the Reynolds number leads to an increase in the heat transfer efficiency in the case of the loop flow while in axial flow designs, heat transfer in the cavity decreases sharply with a decrease in the spacing between the disc bosses and reaches a minimum in a closed cavity. Figures 5; references 2.

Low-Frequency Vibrations of Adjustable Laval Nozzle Blades in Gas Turbine Engines

927F0210K Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 48-52

[Article by Yu.I. Tsybizov; UDC 621.45:533.6]

[Abstract] The design of the adjustable Laval nozzle sub- and supersonic blade rims used for maximizing the fuel efficiency and thrust of modern supersonic jet engines is described and a complex of studies which made it possible to reproduce the process mechanism in such engines on a scaled-down and simplified model developed by V.V. Rogalev is outlined. Slow motion films show that the during the low-frequency vibrations developing in the blades, they perform regular periodic motions in the transverse cross section of a right circle. The conditions under which the low-frequency vibrations develop are formulated and the factors causing them are identified: during rapidly variable pickup processes in transient conditions with certain nozzle outlet and throat section; in the presence of a considerable nozzle contour break and at low natural frequencies of the structure; and in the presence of a large associated volume serving as a Helmholtz resonator communicating with the outer medium only through the circular cross section. An equation is derived for the low-frequency vibration appearance and a range of practical measures aimed at eliminating low-frequency vibrations is outlined, primary profile optimization of the subsonic section. Figures 3; references 2.

Stability of Thin-Walled Sheet Blanks Under Face Rolling of Edges by Roller

927F0210L Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 52-56

[Article by S.A. Zharkov, V.I. Yershov; UDC 621.735.4]

[Abstract] The process of steady-state face rolling of a thin-walled sheet blank by a free roller whereby the blank edge is plastically deformed and all of its metal is either used to increase the sheet blank edge without changing the planeness of its median surface or forms a longitudinal ridge with a slight change in the edge thickness is considered and the energy condition of face rolling without a loss of stability is derived. The extremal principles of the mechanics of continua are used to solve the problem of face rolling without a loss of stability and the experimental values are compared to the results of experiments where sheet blanks from 1-2 mm thick AMg3M and AMg6M alloys are rolled by a roller with a 50 mm radius. The stable rolling condition is analyzed on an SM-4 computer. Figures 4; references 3.

Using Numerical Method To Solve Problem of Simple Elastoplastic Bending of Thin Blanks Allowing for Geometrical Nonlinearity

927F0210M Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 56-61

[Article by I.M. Zakirov, M.I. Lysov, N.M. Bodunov; UDC 539.3:621.981:624.072]

[Abstract] A wide range of geometrical nonlinear problems arising in practical analysis of machine parts and elements under both plastic and elastic deformation stages is discussed and a numerical method is proposed for analyzing thin rods under various boundary value conditions and arbitrary loads. The method is especially accurate and is characterized by the simplicity of initial data assignment and versatility of the mathematical model used for this purpose. The method makes it possible to take into account the physical process nonlinearity in addition to the geometrical nonlinearity. For illustration, bending of a cantilever beam (or rod) is considered and the law of the force vector variation is examined. It is assumed that the load is applied quasistatically while the deformation process is represented by a succession of equilibrium states. The problem is realized on a unified system (YeS) computer in the Fortran language. The solution is based on reducing the initial differential boundary value problem to a discrete problem with the help of the finite difference method. The proposed procedure for analyzing large displacements under simple elastoplastic bending of thin cantilever rod blanks is suitable for solving various practical problems which amount to defining the boundary value conditions and external loads. Figures 2. tables 1; references 10: 9 Russian, 1 Western.

Active Spacecraft Deceleration in Planet Atmospheres Using Braking Propulsion Unit Block

927F0210A Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 3-8

[Article by V.T. Kalugin, A.Yu. Lutsenko; UDC 533.6.011]

[Abstract] Passive (aerodynamic) and active (jet) methods of controlling the spacecraft's (KLA) aerodynamic characteristics during the reentry and soft landing and the aerodynamic interaction of the single central jet of a braking propulsion engine—the retrojet—with the approach flow are discussed and the results of aerodynamic research into various versions of descent modules (SA) with an active braking system within an $M_{My} = 2\text{-}4$ range, an attack angle range of $\alpha = 4\text{-}16°$, and an injection intensity range J of 0.122.5 are presented. It is established that the behavior of aerodynamic coefficients is determined by the flow structure near the model surface which, in turn, depends on M_{My}, J, and α, and the relative total mass rate of the injected substance. Five possible streamlining shapes are established on the basis of shadow photographs of the flow. An analysis of experimental data confirms the advantage of using braking propulsion engine (TDU) with a block of nozzles placed around the descent module periphery over a single centrally located engine. Criteria of the transition from one of the five flow structure to another are identified and the corresponding change in the aerodynamic characteristics is established on the basis of a physical model within the entire engine thrust range. Figures 3; references 4: 2 Russian, 2 Western.

Heat Exchange and Friction Loss Analysis of Turbulent Flow in Discretely Rough Channels

927F0211C Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 69-72

[Article by V.V. Olimpiyev; UDC 536.24+532.5]

[Abstract] A model and a procedure for analyzing the boundary turbulent flow around discrete transverse ridges in a channel are proposed and the effect of the eddies generated by the ridge on the heat and momentum transport in the boundary layer downstream from the ridge whereby the eddies serve as the external flow turbulence is discussed. It is shown that the low ridge height and boundary layer thickness make it possible to simulate the flow around the ridge in the channel by the flow on a planar wall. The boundary layer is analyzed downstream from the reattachment point. The model is suitable for a wide range of Prandtl numbers and can be used for analyzing the heat exchange and friction in a rectangular channel with ridges on one wall used for cooling turbine blades. A comparison of experimental and theoretical data demonstrates their adequate consistency for nonsmooth pipes, annular channels, and tube bundles. It is shown that additional heat transfer intensification under rotation in a radial-flow cooling turbine blade channel can be taken into account with the help of the enhancement factor. Figures 1; references 12.

Performance and Economic Efficiency Estimation Criteria of Electric Power Distribution Systems on Civil Aviation Aircraft

927F0211A Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 62-65

[Article by V.I. Kriventsev, V.V. Drozdov; UDC 621.316.174:629.13.001.24]

[Abstract] The issues of estimating the efficiency of vehicle electric power plant equipment (*Izvestiya AN SSSR: Energetika i transport* No 1, 1978, pp. 36-41 and No 1 1979, pp. 123-132) are considered and it is suggested that specific outlays for electrical equipment maintenance and operation which can be evaluated by the sum of their specific components per hour of aircraft flying time be used as the criterion. Formulas and correction factors are derived for each specific outlay component making it possible to take into account the performance and operating efficiency indicator variations and discrepancies between the start of equipment operation and its manufacturing date. The values of indicators are summarized for three types of electric wires: BIF, BPDO, and BPDOA. The proposed criterion is tested in optimization analysis on a computer for an

AN-124 aircraft. The efficiency assessment criterion takes into account such basic technical, economic and performance characteristics as electric power network cost and reliability, maintenance cost and labor outlays, and cost of electric wiring and is suitable for determining the technical, economic, and performance efficiency of civil aviation airplane electrical distribution networks. Tables 1; references 3.

Peculiarities of Today's Development Trend in Electrostatic Motors and Various Electrostatic Plants

927F0211D Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 72-75

[Article by L.A. Latyshev, N.A. Maslennikov, N.N. Semashko; UDC 621.455:658.512]

[Abstract] A new trend in science and engineering related to the use of plasma and ionic devices which has emerged in recent years, especially in the field of electrostatic accelerators in which the directional speed of charged particles is incremented virtually without collisions under the effect of an electric field, making it possible to attain a high energy efficiency, a low flux divergence, and an extended normal life, is discussed. A trend toward maximizing scientific and engineering designs and ready items well-proven in operation and a transition from the "do all you can" to the "do all you can afford" principle is outlined and it is noted that although serious research is urgently needed, the R&D cost is much lower than the cost of development and implementation. The importance of selecting optimum standard sizes for increasing the utilization efficiency of research-intensive products is stressed and the issue of selecting quality criteria is electric rocket engines is addressed. The experience of the Livermore Laboratory in the United States showing that for each developer there should be two designers, one product engineer, and six to eight skilled workers is reviewed. The conclusion is drawn that possible R&D operations must be carefully analyzed and expanded before making the decision on whether or not pursue certain project. Figures 2; references 4.

Local Heat Transfer in Perforation Channels of Turbine Nozzle Vanes

927F0211E Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 75-77

[Article by K.M. Iskarov, O.Ye. Solodovnikov; UDC 536.24:621.438]

[Abstract] The factors affecting the heat transfer coefficient selection in determining the thermally stressed state of gas turbine blades and vanes with perforation channels for releasing the cooling air on the vane's outside surface and the drawbacks of the criterial dependence for the mean heat transfer in the perforation channels in determining the temperature patterns of the relatively thin perforated blade wall are discussed and a computational experiment aimed at finding the temperature state of the cylindrical element with a perforation channel—a part of the blade wall under the boundary value conditions typical of high temperature gas turbine engine blades—is outlined. Two version of boundary value conditions on the cooling air side in the perforation channels are specified. It is demonstrated that failure to take into account the heat transfer coefficient variation along the channel length may result in 5-25K errors of the temperature state of blades with perforation channels, depending on the relative channel length and, consequently, in a need to study local heat transfer in the turbine blade perforation channels. A unit used for conducting such a study is described and the local heat transfer change along the channel length and the mean heat transfer in various channels are plotted. Cylindrical tubes from the 12Kh18N10T alloy with a ratio of $l/d = 1$ and 4 (relative channel length) are used. A nonstationary research method is employed in the experiment. The study reveals that the character of heat transfer behavior as a function of the relative coordinate x/d at various Reynolds numbers is the same, making it possible to generalize the results as a similarity equation; the approximation error does not exceed 18%. Figures 4; references 8.

On Analyzing Equilibrium Compositions. Introduction of Continuity

927F0211F Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 78-80

[Article by R.R. Nazyrova, A.A. Dregalin, D.G. Novikov; UDC 536.03]

[Abstract] Application principles of the method of introducing continuity to the solution of the problem of equilibrium composition analysis and the principal requirements imposed on today's algorithms, i.e., sufficient computation speed, are presented and it is noted that the stepwise method of analyzing heterogeneous systems greatly slows down the computation process. Thus, a comprehensive method based on the substitution of variables, i.e., on switching from the p_{jk} variables for substances in the gaseous state to the n_{jk} variables for substances in the condensed state, is proposed. To this end, a multicomponent system consisting of condensing and gaseous molecular and atomic substances is considered and the values of variables which meet the condition of equilibrium composition are derived. The resulting system of equations is nonlinear and preserves continuity both with the appearance and disappearance of the condensed phase. Newton's method is used to solve the system of equations; the solution is eventually reduced to multiply solving a linear system of equations produced by linearizing the initial equations. The

method is characterized in that it contains no indeterminate parameters. Test computation on a computer with the help of the proposed method demonstrates its sufficiently high mobility. References 4.

On Simulating Combustion Process With Delay in Solid Propellant Rocket Engine

927F0211G Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 80-84

[Article by Yu.S. Shatalov, I.I. Dotsenko, I.M. Urakayev; UDC 536.46]

[Abstract] Combustion rate delay relative to the pressure in the combustion chamber (KS) is considered as one of the reasons for combustion instability in solid propellant rocket engines (RDTT) and new data on the combustion process with delay which make it possible to reevaluate the problem of abnormal phenomena in solid propellant rocket engines, mostly propellant with $\nu<0$ where ν is the exponent in the solid propellant combustion law, are presented. The propellant charge combustion assumptions are outlined and the equation of conservation of gas mass, the equation of state of ideal gas, and the rate equation of combustion with delay are used to simulate the combustion process with delay. Three particular cases of the problem which have practical applications are considered. The dependence of the gas pressure in the solid propellant rocket engine combustion chamber on time, the stability domain of solutions of the steady-state gas pressure equation, and the dependence of the gas pressure in the combustion chamber on time are plotted. An analysis of the findings confirms that delay may significantly affect the operation of solid propellant rocket engines. Figures 4; references 8.

Investigation of Temperature Field of Finned Heat Pipe Radiator

927F0211H Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 84-88

[Article by V.L. Shur, A.L. Luks, Ye.Yu. Lempert; UDC 629.78.048.7]

[Abstract] Convective radiators which are used as a component of an aircraft temperature control system and are intended for releasing heat into the air under poor convection conditions, particularly heat pipe radiators, are considered. These heat pipes make it possible to lower the temperature difference on the radiator surface and increase the integral mean temperature of the radiating surface and thus decrease the radiating power at a smaller radiator area. The effect of the heat pipe positioning on the radiator's temperature pattern is characterized by the need to consider a two-dimensional radiator model allowing for the heat exchange processes inside the heat pipes. The temperature field equations are derived for a single structural member; they describe the radiative-convective heat exchange between the fin and the heat pipe wall under a uniform external radiation load allowing for the heat transfer during the coolant phase transformations inside the heat pipe. The equations are linearized and solved by the successive approximation method for the nondimensional coolant saturation temperature. The temperature field is plotted, making it possible to determine the radiator and heat pipe capacity and to optimize the radiator configuration and the number of pipes and their characteristics at the design stage. Figures 4; references 4.

On Pressure Recovery Coefficient

927F0211I Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 88-93

[Article by N.A. Shushin; UDC 533.0:532.526]

[Abstract] The use of unidimensional representation of the pressure recovery coefficient in engineering analyses of gas flows which takes into account various losses in the flow is discussed and the pressure recovery coefficient is considered in conjunction with the boundary layer displacement thickness. The relationship between the cross section areas of an ideal flow and a flow with losses is derived and an attempt is made to demonstrate that similar relationships are also valid for the boundary layer. The rate of flow across the boundary layer is determined and a formula for the relative layer displacement thickness is derived on its basis. The problem of the pressure rise in the boundary layer drain channel at hypersonic velocities of the external flow is solved graphically and the flow conditions in wind tunnels at low Reynolds numbers with fully converging boundary layers on the nozzle exit section is plotted. The gas dynamic functions in such a wind tunnel is expressed through the Mach number and the change in the working pressure ratio in it is estimated. The findings show that the effect of the Reynolds number in wind tunnels with a very short working section is very small. It is speculated that the proposed method of modifying the flow and assigning the losses in the flow to a certain fictitious relative displacement thickness makes it possible easily to solve important application problems. Figures 2; references 2.

On Certain Design Features of Multirow Ball Hardeners for Surface Cold Working of Parts

927F0211J Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 93-95

[Article by P.G. Balyura, G.S. Gorshenin; UDC 621.7.014.015]

[Abstract] An engineering design is proposed for the method of finishing treatment of cylindrical parts by surface plastic working (PPD) and the design of an original rotary ball head structure for hardening surface

consisting of individual disc sections forming separating grooves with balls at an acute angle which ensures the machining uniformity is presented. The quality of the surface machined by such a multitool rotary ball head is characterized by the surface finish class and the degree of surface cold working; roughness, in turn, depends on the number of ball impressions per unit of machined surface area. Balls from the ShKh15 steel are used in the machine described. A pilot commercial trial to verify the analytical results shows that the machined surface roughness is characterized by an arithmetic mean deviation of the profile $R_a = 0.8\text{-}1.2\ \mu m$ and a cold working degree of $\varepsilon = 25\text{-}30\%$ for a machine with 40 balls at a 250 RPM part rotation speed, an 800 RPM head rotation speed, and a 0.52 mm/rev feed per part rotation. The machining efficiency under such conditions is 1.5 higher than that of existing methods. Figures 2.

Representation of Function of Many Variables Using Besier Curve Frame

927F0211M Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 103-106

[Article by E.B. Mats, A.V. Shcherbakov; UDC 629.7.036:681.3]

[Abstract] The issue of representing various empirical relations defined on a point basis which often arises in developing CAD mathematical models is addressed and a method which makes it possible to approximate multivariate functions and calls for relatively small computer resource outlays is proposed. The method is based on the frame method of surface representation whereby the surface is substituted with a set of frame lines or branches while the coordinates of the intermediate points are determined by interpolation. This concept is extended to a hypersurface, making it possible to represent an arbitrary multidimensional function as a set of branches each of which is a function of one independent variable derived for a certain combination of the remaining independent variables. The branches, in turn, are approximated with the help of Besier's function. The criteria for selecting this function are described. To lower the fluctuation probability, a polynomial with a power of no more than six is used in the interpolation procedures. Several algorithms realized as a software package in the Fortran language for a PC-type microcomputer are tested by approximating the characteristics of turbines and compressors with up to seven independent variables. Third-order Besier curves are used in approximation, ensuring accurate results within 0.2-0.3% while reducing the volume of data used in the spline method by almost twofold. The resulting transfer model ensures an accuracy within 1-1.5% compared to the initial model. Figures 2; references 2.

Computer-Aided Workstation for Partial Scale Tests of Aircraft Stabilization Loop

927F0211L Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 99-103

[Article by V.I. Kruglov, A.A. Lisov, V.Ye. Shevchenko, T.A. Chernova; UDC 629.018]

[Abstract] The use of partial scale simulation (PNM) for refining the parameters of real aircraft stabilization loop equipment (KS) during its manufacturing and ground tests and the components necessary for implementing the method are outlined and the shortcomings of traditional approaches to aircraft stabilization simulation are discussed. A computer-aided workstation (ARM) for partial scale stabilization loop simulation which makes it possible to solve the problem of increasing the analysis reliability and is free from its predecessors' drawbacks is proposed and its block diagram is cited. The simulation problem is solved most efficiently with the help of the proposed workstation using hybrid computer systems (GVS) containing analog and digital processors, e.g., an AVK-32 third-generation analog computer system and an Elektronika 100-25 microcomputer; the machines are linked by a BSK-31 interface module which is expanded for using the unibus architecture. The workstation is designed for lay users without special programming experience. Implementation of the new computer-aided workstation helps to maximize the software versatility for various types of aircraft and the capabilities of today's computer systems. The resulting possibility of using analog-digital routines accelerates the study of complicated dynamic entities thus increasing the simulation and evaluation accuracy and shortening the test duration. Figures 2; references 3.

Procedure for Estimating Technical and Economic Efficiency of Measures Which Increase Operating Reliability of Aircraft Gas Turbine Engines

927F0211K Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 95-99

[Article by A.I. Yevdokimov, A.I. Rydayev; UDC 621.438.003.13]

[Abstract] The basic premises of a mathematical model which describes the effect of various measures aimed at decreasing premature engine retirement (DSD) on the integral reliability indicators of gas turbine engines (GTD) are outlined and an attempt is made to analyze the technical and economic efficacy of these measures which are understood as the use of various design, process, management, and other solutions aimed at lowering premature engine withdrawal from service due to various reasons and decreasing the technical and economic outlays for the aircraft (LA) pool operation. To assess the efficiency of each measure, its effect on the gas turbine engine reliability indicators is simulated for

individual causes and as a whole. An algorithm is developed for computing the reliability indicators after taking specific measures; some of the measures are illustrated by a device preventing the ingress of extraneous objects into the engine which is characterized by the separation coefficient. An example of the gas turbine engine reliability indicator calculation after a protective measure in the form of a grate located in front of the engine intake has been taken is cited. The findings indicate that this measure is expedient since integral reliability indicators improve after its implementation; e.g., the time in service rose form 1,500 h to 2,743 h while the longevity index increased from 729.9 to 838. It is noted that not every measure, even if it increases the reliability characteristics, is suitable for implementation and that each version needs an individual feasibility analysis. Figures 3; tables 1; references 2.

On Effect of Fluid Vibrations Excited During Drainage on Remaining Fuel

927F0211B Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 91 pp 65-68

[Article by N.Ye. Boytsun; UDC 629.78.01:532.59]

[Abstract] The importance of maximizing the fuel utilization for designing aircraft fuel tanks is noted and the effect of the free fuel surface vibrations caused by the aircraft's transverse vibrations and turns as well as by the fuel drainage process itself on the remaining fuel (GO), i.e., the fuel trapped in the tank when gaseous inclusions break through into the drain line, is discussed. Attention is focused on the effect of the second factor which has hitherto been virtually ignored in scientific publications. A "syringe" injection unit used in the experiment is described and the dependence of the unusable fuel on the initial filling volume and the dependence of the initial filling volume leading to the maximum unused fuel amount on the Froude number are plotted. The curves make it possible to calculate the frequency of the free fuel surface vibrations during the drainage; the findings indicate that the frequency of axisymmetric vibrations is comparable to that of the first harmonic of axisymmetric vibrations. It is speculated that the findings make it possible to find new ways of solving the problem of minimizing the amount of unusable fuel. Figures 3; references 4: 3 Russian, 1 Western.

On Flow Mixing Enhancement Downstream From Oblique Shock Wave

927F0207B Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Mar-Apr 92 pp 61-68

[Article by V.I. Vasilyev, S.N. Zakotenko, Moscow; UDC 532.525.2:533.6.011.5]

[Abstract] The behavior of hypersonic wakes with a decrease in the Mach number is addressed and the possibility of enhancing mixing in the case where the theoretical wake passes through a stationary oblique shock is examined. To this end, two types of jets are considered: planar and spatial wakes either of pure helium or air with helium behind a nozzle with a square exit section. To describe the turbulent flow in the wake, a single-parameter turbulence model which makes it possible to take into account the effect of the Mach number on the turbulent viscosity genesis in the mixing zones is used. The adequacy of the analytical model is checked by comparing the computed data to experimental results. The study shows that turbulent viscosity in both spatial and planar jets interacting with an oblique shock undergoes virtually no change, i.e., the flow is not turbulized, while the jet cross section becomes deformed. In addition to the cross section deformation observed in the planar flow, the spatial jet shape is additionally distorted due to the secondary flows downstream from the shock. It is demonstrated that mixing is enhanced rather noticeably behind the shock due to the predominant lateral strain while the secondary flow's role is not significant. It is shown that approximate formulas can be used for calculating the mixing. The authors are grateful to V.A.Stepanov for constructive discussions. Figures 6; references 9: 6 Russian, 3 Western.

Variational Problem of Profile Optimization of 'Lateral' Supersonic Section Walls of 'Narrow' Three-Dimensional Nozzle

927F0207C Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Mar-Apr 92 pp 102-112

[Article by A.N. Krayko, A.R. Polyanskiy, N.I. Tillyayeva, Moscow; UDC 533.6.011.5:517.97]

[Abstract] The lateral wall profile of the supersonic section of a three-dimensional nozzle with two planes of symmetry which develops the maximum thrust at specified sub- or supersonic flow at the inlet is optimized in a narrow channel model approximation which reduces the three-dimensional flow to a two-dimensional one. A variational problem of supersonic nozzle profile optimization is formulated allowing for dimensional constraints. In a general case, the variational problem is solved approximately while in the case of nozzle with nondiverging end sections of the upper and lower walls the solution is strict. The dependence of the nozzle thrust on the inlet section configuration is examined and an approximate method of profile optimization of cylindrical lateral walls for specified upper and lower walls is proposed. In all cases, nozzles whose height changes slower than width are considered. The authors are grateful to L.Ye. Sternin for stimulating their interest in the subject and V.A. Vostretsov for assistance. Figures 2, tables 1; references 12.

Numerical Simulation of Supersonic Flows Near Airfoils With Various Sweep Angles Within Broad Range of Angles of Attack Using Planar Section Law

927F0207D Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Mar-Apr 92 pp 113-120

[Article by N.V. Voyevodenko, I.M. Panteleyev, Moscow; UDC 533.6.011.5:519.63]

[Abstract] The problem of the flow around thin bodies at hypersonic velocities at arbitrary angles of attack is considered in the framework of the planar section law, or Sychev's theory. The difficulty of engineering methods is discussed and it is speculated that Sychev's theory in combination with the numerical method make it possible to solve the problem of flow about a wide range of bodies at hyper- and supersonic velocities accurately and quickly enough. A solution procedure is formulated and a solution routine is derived on its basis. The planar section law equations are integrated by Godunov's method. A flow of ideal gas is considered in the problem where the approach flow's Mach number is M. The three-dimensional steady-state equations and boundary conditions describing the initial problem are transformed to two-dimensional nonstationary conditions whereby the time axis is directed along the body axis. A routine for numerically integrating the generalized planar section law equations by Godunov's method is described. The results of hypersonic flow analysis of axisymmetric bodies using this routine are compared to experimental data and the results obtained by other authors. The comparison demonstrates adequate consistency up to attack angles of close to 90°. Figures 5; references 10: 7 Russian, 3 Western.

Method of Determining Aerodynamic Coefficients of Asymmetric Bodies Allowing for Nonlinear of Body Form Effect Factors

927F0207E Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Mar-Apr 92 pp 121-128

[Article by G.G. Skiba, V.M. Yurov, Moscow; UDC 533.6.011.55]

[Abstract] The supersonic flow of a nonviscous nonheat-conducting gas around an asymmetric body with a rather arbitrary cross section shape, e.g., square, elliptical, triangular, or a combination of a circle and an ellipse, etc., is considered in a Cartesian system of coordinates which corresponds to a cylindrical system of coordinates used for numerical integration of a system of gas dynamics equations. An equation describing the asymmetric body surface is derived. The proposed numerical method makes it possible to determine the aerodynamic coefficients of asymmetric bodies at low spatial angles of attack and ensures an aerodynamically sound transition from a three-dimensional system of gas dynamics equations to two-dimensional, thus greatly simplifying the task and decreasing computer time outlays by tenfold. The coefficient is calculated rather accurately for asymmetric bodies even when the angle ψ between the symmetry plane and the angle of attack plane is not equal to zero. The values of the aerodynamic coefficient are determined relative to the center of the spherical body's blunting. The method also takes into account the effect of nonlinear body form factors on the coefficients thus greatly increasing its accuracy. Figures 2; tables 2; references 5.

Analysis of Three-Dimensional Boundary Layer on Leeward Side of Delta Wing of Finite Length for Conditions of Viscous Interaction With Hypersonic Flow

927F0207F Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Mar-Apr 92 pp 129-136

[Article by G.N. Dudin, Moscow; UDC 533.6.011.55:532.526.2-3]

[Abstract] The hypersonic flow of a viscous gas around a thin delta wing of finite length at a small angle of attack α^0 approximately equal to $Re_o^{-1/4}$ is considered in a body-axes system of coordinates with an origin at the delta wing apex assuming that in the flow around the wing, the condition of viscous interaction of the three-dimensional boundary layer with an external nonviscous flow is realized. In solving the boundary value problem, the flow in the wake is ignored and the boundary value condition is defined on the leeward side of the delta wing. Since the flow is around a slab with a nonzero enthalpy and the flow itself is subcritical, the pressure distribution function is also defined in order to select the unique solution. The parameters of the three-dimensional boundary layer on the lee side of the wing are determined and its aerodynamic characteristics are analyzed. A considerable decrease in the pressure on the wing's leeward side with an increase in the angle of attack is noted. The dependence of the aerodynamic coefficients on the angle of attack is greater at an interaction parameter of $\zeta_* = 0.8$ than at $\zeta_* = 2$ due to the greater change in the pressure distribution along the wing with a change in the angle of attack in this case. Figures 6; references 10: 6 Russian, 4 Western.

On Certain Regimes of Supersonic Flow Around Windward Side of Swept Back Wings

927F0207G Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Mar-Apr 92 pp 137-150

[Article by M.A. Zubin, N.A. Ostapenko, Mechanics Institute at Moscow State University; UDC 533.6.011.72]

[Abstract] The conditions under which the flow regime discovered in the theory of ideal gas with an emersed

Ferri point on the windward side of a wing with supersonic leading edges and the breakdown of the conical flow in the presence of turbulent boundary layer separation are investigated using three models of swept back wings with sharp leading edges and a 40° sweep angle and 30, 45, and 90° side tip apex angles. Optical methods which make it possible to observe shadow patterns of the flow in the plane normal to the edge of the swept back wing and the method of oil-and-soot visualization are used in the experiment. The effect of the shock wave interaction with the boundary layer on the wing walls on the total flow pattern is considered. It is shown that the gas viscosity at high angles of incidence leads to the appearance of new characteristics in the disturbed flow which are concomitant with the Ferri point emersion. In the cases where the Ferri point emersion is realized in the theory of ideal gas in the symmetry plane of the flow on the windward side, it also occurs in real flows. The conical flow breaks down, i.e, the shock wave diverges from the swept back wing apex, due to the inner shock transition from the weak to the strong family. The study thus shows that in the presence of a boundary layer separation in the disturbed flow area, the results of the ideal gas theory cannot be used for the conical flow. Figures 9; references 12.

Effect of Longitudinal Riblets on Axisymmetric Body's Drag

927F0207H Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Mar-Apr 92 pp 174-178

[Article by S.F. Konovalov, Yu.A. Lashkov, V.V. Mikhaylov, I.V. Fadeyev, G.K. Shapovalov, Moscow; UDC 532.5.013.12:532.517.4]

[Abstract] The urgency of lowering the drag at turbulent conditions and improving the aerodynamic cleanness of subsonic aircraft by microfinning the aircraft airframe is noted and the results of comparative weight measurements of the total drag of an axisymmetric body with smooth and ribleted cylindrical surface section are discussed. The tests are carried out in a closed-circuit wind tunnel at an initial circuit pressure of 0.5 and 1 atm with an artificial model boundary layer turbulization where the approach flow Mach number changes within 0.15-0.85, the Reynolds number—within 4 x 10^6 to 30 x 10^6, and the angle of attack α—within 0-12°. The model is fastened to the platform of a six-component wind tunnel balance with two lateral X-shaped strips and one sagittal nose strip. The maximum total drag gain attained in the model with riblets reaches 8%. Most of the gain is attributed not only to a decrease in the friction stress on the riblet surface but also to the flow modification on the smooth section downstream along the diffuser section. From the viewpoint of decreasing friction, the optimum finning pitch is 14. Figures 5; references 10: 4 Russian, 6 Western.

On Viscous Instability of Hypersonic Flow Around Wedge

927F0207A Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Mar-Apr 92 pp 55-60

[Article by I.V. Savenkov, Moscow; UDC 532.517.2.013.4:533.6.011.55]

[Abstract] The effect of shock waves and entropy layers on the stability of hypersonic flows, particularly viscous and nonviscous modes, is discussed and the effect of shock waves on the propagation of two-dimensional viscous modes under hypersonic interaction conditions is investigated. To this end, the specific issue of viscous instability of the hypersonic flow past a wedge is considered and it is demonstrated that two-dimensional modes have a greater incremental increase on the scale of Mach numbers than the modes described by Cowley and Hall and are therefore more dangerous from the viewpoint of the laminar-to-turbulent transition. The equation of motion is derived for the uniform hypersonic flow past a thin wedge with a sharp point. An asymptotic analysis reveals that although the presence of shocks waves in the flow may result in a viscous flow instability, this rule is not universal and applies primarily in the cases where the shock waves approaches the streamlined surface closely enough. The resulting viscous instability is characterized by the presence of a countable number of alternating local perturbation buildup increment maxima and minima which may be interpreted as branching of the dispersion ratio root into a denumerable number of unstable roots. The presence of a countable number of local maxima whose magnitude increases from peak to peak may lead to a qualitative singularity of the wave packet development. The author is grateful to the participants in O.S. Ryzhov's seminar for discussing the findings. Figures 2; references 5: 3 Russian, 2 Western.

Investigation of Active Media of a Shortwave Gas-Dynamic Laser

927F0188A Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 2, Feb 92 (manuscript received 3 Jul 91) pp 165-173

[Article by S.V. Makarychev and G.D. Smekhov, Moscow; UDC 533.6.011.8:535.374]

[Abstract] Gas-dynamic lasers are currently the most powerful continuous-wave lasers used in industry and scientific research. They have a lasing power of 10^4-10^5 W. Their operation is based on optical transitions between the oscillation energy levels of CO_2 molecules and their active medium forms as the working gas cools while flowing through a supersonic nozzle. High gas flow rates help increase the laser's power. One pressing problem with the field of gas-dynamic lasers is that of creating high-power lasers in the shorter-wave regions of the spectrum. In an effort to solve this problem, the authors of the study reported herein conducted a theoretical and experimental investigation of the process of the formation of visible- and ultraviolet-range active media in a flux of recombining plasma through a supersonic nozzle. First, they use an approximate method of calculating a nonequilibrium flow of highly ionized plasma to theoretically analyze the development of the main types of nonequilibrium resulting in an inversion in the active medium of a gas-dynamic laser. The method is based on dividing the flow into equilibrium and ionization-frozen segments and may be considered an analogue of the "instantaneous freezing" method that is used in modeling nonequilibrium flows of diatomic disassociating gases. The method is based on a system of equations of the stationary quasi-one-dimensional flow of multicomponent, two-temperature, ideal, single-velocity nonequilibrium plasma. The difference between the characteristic relaxation times of the excited levels and the change in gas-dynamic parameters makes it possible to divide the equation system into two subsystems: plasma-dynamics equations and equations of the kinetics of the population of the excited levels. The researchers tested the validity of their computation method by conducting a series of experiments. In the experiments they used highly ionized xenon plasma generated by pulsed gas-dynamic sources of the "shock tube with a nozzle" type. The succeeded in amplifying the radiation in the blue-green region of the spectrum at the $6p^4D_{5/2}°$-$6s^4P_{5/2}$ transitions (wavelength, 0.5419 μm) and $6p'^2P_{5/2}$-$5d^2D_{5/2}$ (wavelength, 0.4973 μm) of the XeII ion. A comparison of the experimental and calculated inversion regions for the transition at 0.5419 μm revealed that the computation method yields slightly smaller inversion regions than actual experiments do. The theoretically and experimentally determined threshold temperature (14,000 K) and gain factor at the maximum (about 0.04 cm^{-1}) did turn out to be in good agreement with one another, however. Figures 4, tables 2; references 15: 11 Russian, 4 Western.

New Standard for Optical Rangefinders

927F0103A Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 10, Oct 91 pp 52-54

[Article by G.S. Kryukov, A.S. Sushkov, and R.A. Tatevyan; UDC 528.51(083.133)]

[Abstract] The new All-Union State Standard 19223-90 "Optical Rangefinders: Geodetic" classifies these instruments into four groups: SG rangefinders for the state-operated geodetic grid, SP rangefinders for applied geodesy, ST rangefinders for development of geodetic bunching grids, STD topographic rangefinders operating in the diffuse reflection mode. The basic common metrological performance criterion for all optical rangefinders is the allowable r.m.s. error of distance measurements in one run $m_D = a + bD.10^{-16}$ (a,b- constants characterizing the measurement error; D- measured distance), the values of both constant as well as the range of measurable distances from minimum to maximum being specified for each group. The standard stipulates formulas for calculating those two constants a,b. The standard retains the earlier requirement of a certification test, periodic inspection, reliability tests, and environmental tests, the main criteria for acceptance being accuracy and stability. The standard adds a set of new technical requirements all optical rangefinders must meet, these requirements being defined in terms of upper limits on: 1) deviation from parallelism, 2) standard deviation of distance readings, 3) systematic error of distance measurements, 4) standard deviation of cyclic instrument error, 5) deviation of actual scale frequency from nominal at all operating temperatures at (a) producer's site and (b) six months later at user's site, (6) warm-up time. Unlike the previous standard, the new one includes a list of functions an optical rangefinder must perform within the scope of its specific application. The new standard takes effect on 1 July 1991.

Planimeters PP-M

927F0100B Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 8, Aug 91 pp 47-48

[Article by N.G. Suponya; UDC 531.72]

[Abstract] The "Temp" Cooperative of the "Lvovpribor" (Lvov Instrument) Industrial Association has begun producing mechanical polar planimeters PP-M. Its design is a modified and simplified version of the "Baku" single-carriage version. While the structure of the polar coordinate plotter is better, the new version has several flaws: 1) the needle which replaces the optical tracer is less convenient to operate and can easily get lost; 2) the vernier for setting the length of the tracer arm has been eliminated, which lowers the precision of this operation by one order of magnitude; 3) the tracer has been poorly designed with a for no good reason movable head at the end of the arm, its movements causing uncontrollable changes of the arm length and thus also changes of scale; 4) the locking wheel is made of a soft metal so that its teeth wear fast and operation of the

counting mechanism soon becomes unstable. Unlike in the MIIZ (Moscow Institute of Land Use Measures Engineers) planimeter with the axle of the locking wheel running two adjustable jewels, in the PP-M planimeter one of the two jewels is not adjustable so that setting the clearance between the locking wheel and the vernier is more difficult. The eccentricity of the locking wheel can, moreover, reach 0.05 mm and thus exceed the maximum allowable and its rough teeth may tear the paper. Owing to these and a few other flaws, the PP-M planimeter is inaccurate and not usable. Unless its design can be improved, it will have to be redesigned.

Testing of "Trap" Radio Rangefinder on Sviritsa Geodetic Polygon

927F0100A Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 8, Aug 91 pp 45-47

[Article by Ya.M. Kostetskaya and A.V. Yuskevich; UDC 528.517]

[Abstract] The semiautomatic "Trap" radio rangefinder consists of two or three interchangeable radar sets operating pairwise in the 3 cm wave band in the driving mode at a different single carrier frequency each. It is designed to measure distances ranging from 50 m to 15 km at four scale frequencies of the order of 15 MHz. The difference between the two carrier frequencies of radar sets is preset before measurements and then automatically held constant during measurements. The two quartz oscillators operate in the driven mode, the frequency of each also being trimmed automatically. Each radar set is powered by a 12 V storage battery. This rangefinder was in October 1987 tested for accuracy on a geodetic polygon on the east coast of Lake Ladoga. The polygon enclosed a territory with a sloping ground surface, the differences of altitude not exceeding 50 m. The territory extended over grassland and underbrush, some thin woods, some farm land, and some parts of the lake surface. The polygon lines, their length ranging from 200 m to 36 km, were anchored 1.8 m deep and passed over different terrains so as to make the altitude of level rods vary: two lines passed almost entirely over water, the others passed partly over water and partly over dry land. Signals were placed at six points, plumbs were placed at all others points. Measurements were made mostly from 10 AM to 2 PM under the following weather conditions: air temperature varying from -5°C to 3°C, air pressure varying over the 776-782 mm Hg range, wind light to moderate, variable cloudiness without precipitation. For an accuracy evaluation of these measurements, a part of the polygon territory was in 1988 surveyed with the four-to-five times more accurate "Geodimetr-8" optical rangefinder and its length readings were used as a standard for comparison. On the basis of the differences between "Trap" readings and "Geodimetr-8" readings, the r.m.s. error of "Trap" readings was 6.8 cm, 4.3 cm, or 3.6 cm when measurements were made with two pairs of radar sets (1-2 and 1-3) in three runs, with one pair of radar sets (1-2 or 1-3) in six runs, or with two pairs of radar sets (1-2 and 1-3) in six runs. The results indicate that for high accuracy, the pairing of radar sets must be varied when measurements are made with a "Trap" radio rangefinder.

We Gave It 5 Years in All: The History of the Creation of the First Soviet Atom Bomb

927F0187A Moscow INZHENER in Russian No 11, Nov 91; No 12, Dec 91; No 1, Jan 92

[Three-installment series "'We Gave It 5 Years in All': On the History of the Creation of the First Soviet Atom Bomb" under the "In the Words of an Eyewitness" rubric by Yu. Chernyshev; author's biography by S. Voronin, first deputy chief designer, All-Union Scientific Research Institute of Physics, Lenin Prize laureate, USSR State Prize laureate, and candidate of sciences]

[Part 1. Nov 91, pp 36-40]

[Text]

About the Author

Yuriy Kirillovich Chernyshev is a candidate of technical sciences and is the lead scientific associate at the "special products" development design office.

Yuriy Kirillovich was born in Izhevsk in 1930 into a family of craftsmen. In 1954 he graduated from the design department at Leningrad Shipbuilding Institute and was immediately sent to the developing nuclear industry. He worked as an engineer-designer and lead designer and was the head of the planning and design department of the All-Union Scientific Research Institute of Engineering Physics [VNIITF] in Chelyabinsk-70 for nearly a quarter of a century. In 1967 he was one of a number of defense engineering specialists to be awarded a USSR State Prize for development of a special product and its launch into series production. He was also awarded two Red Labor Banner Orders and two medals and has received departmental distinctions.

The material presented here to the reader is interesting from a historical perspective. It will also interest sector specialists who were previously unaware of all the details because of past restrictions. Naturally, the material does not answer all the questions, and it does not encompass nearly all the problems and participants in the remote events. It does, however, relate the development of events in the way that they were seen by one of the participants in an undertaking that was so big and so important to our country.

From the Author

This material grew totally unexpectedly from a simple article that was written during the process of work on the history of the creation of a special technology and was printed in our design office's wall newspaper PROGRESS under the title "first designer." After discussions with specialists, the article grew into the following manuscript.

The main thing was to tell it all as interestingly as possible and with extreme care. Indeed, you still feel the regime service and its faithful servants who adhere to more instructions than is sometimes warranted by common sense breathing down your back. But time continues to pass, taking with it the deeds of those people about whom one could talk—enterprising, penetrating people with their own unique style of work from whom a great deal can be learned.

Moreover, everything is now known about the work of the first designers of the rocket and spacecraft systems, the aircraft, and the other types of weaponry: S. Korolev, M. Yangel, V. Chelomey, A. Tupolev, V. Yakovlev, V. Myasishchev, A. Mikoyan, V. Petlyakov, etc. There are virtually no publications about the designers of nuclear weaponry in our country, however. Articles written by physicists and scientists on the topic are known, but that still leaves the work of the designers. Their work was no less important and was among the most critical. Because of the work's secrecy, many of their names still remain unknown. The name of the first designer of the Soviet atom bomb has generally been undeservedly forgotten.

After publication of A. Aleksandrov's article "How the Bomb Was Made," former Minister of Medium Machine Building L. Ryabov complained to one of the chief designers of the charge that the words of those designers who made the weapon with their own hands were absent. Was all of it really not being told? And then there were the veterans as well.

In response to the my question, Academician Yu. Khariton said the following: "In the program of operations A. Aleksandrov was assigned the task of creating new materials for the charge but not with designing it, a task with a great many of its own peculiarities. Only once did we invite A. Aleksandrov to our enterprise so that he could see how the bomb was progressing."

This material is already in the sphere of history, especially since its hero is an elderly man who has long retired from active work in the sector. Even the design that was his little baby has served its purpose and is now only of historical interest.

Even in his 80th year he still has his characteristic clearness of thought, calmness of soul, enviable composure, and courage. I could not restrain myself from asking "How have you been able to stay in such good shape?" Smiling, he answered, "In the Caucuses there is a parable of a journalist who, arriving at a mountain village, saw a 100-year-old and asked him "How have you managed to live to such an old age? Do you eat anything special?" "No my dear," came the answer. "Then do you drink something?" "You are making a mistake, my dear. Do you see the flock of sheep down there? For 100 years I have shouted at them....And I never get a sound in reply."

"But that is a joke, and seriously, I have never fussed. In a word, I have always felt that composure is the secret of success in work and long life. And I never tolerated any fuss in developing my designs."

In my conversations with Prof. D. Fishman and other leading specialists who worked in the sector from the

beginning, I never once heard that any of my questions were too delicate owing to regime considerations. Everyone unanimously agreed that it was possible to speak of a great deal and of a great many people without getting into the secret aspects of the topic.

I am not a professional journalist; nevertheless, I hope that I have, if only remotely, succeeded in showing the intensity of the work and the complexity of the design problems that had to be solved. Of course, this is no complete discussion of all the problems but rather materials and reminiscences supplementing the story that has been told.

This material is not the whole story but only a small part of it. I am counting on the reader's ability to see beyond the individual facts or phrases and to capture the spirit of the times.

In conclusion, I would like to express my deep gratitude to academicians Yu. Khariton and A. Sakharov (with whom I was able to talk shortly before his death) and doctors of sciences D. Fishman and V. Tsukerman, as well as candidates of sciences V. Zhuchikhin, K. Krupnikov, and N. Terletskiy and the other scientists and specialists who provided their own recollections of the work, problems, and stages of the path followed.

I especially thank Viktor Aleksandrovich Turbiner for his careful reading of the manuscript and for his valuable comments.

In the hot Moscow summer of 1989 V. Konovalov, the recently appointed minister of the new joint ministry called the Ministry of Atomic Power and Industry, presented engraved watches to the scientists, engineers, and designers who had prepared the first Soviet nuclear experiment in the steppes of Kazakhstan near Semipalatinsk. That was how the 40th anniversary of the event that marked the beginning of the nuclear sector was noted. Unfortunately, the first designer of the first product among those receiving awards was not present among those receiving awards even though he was still alive and residing in Moscow.

It had become, if you please, fashionable to give one's recollections of participating in the creation of the first Soviet atom bomb. A. Aleksandrov, academician and former president of the USSR Academy of Sciences, wrote an article about it. An interview with L. Altshuler, doctor of physical and mathematical sciences, was recently published, and the memoirs of V. Tsukerman and Z. Azarkh recently appeared. The "Reminiscences" of A. Sakharov have been published. It is clear that they knew mainly the scientific side of the matter. In other words, scientists have primarily given their recollections about scientists. There has not been a word from the designers—from those who have their own right to a very important share of the recognition for the creation of weaponry.

In the article by doctor of technical sciences Golovin in the newspaper TRUD entitled "Culmination," general N. Dukhov, chief designer of the KV heavy tank, was named chief designer of atomic weaponry and deputy of Scientific Director Yu. Khariton. N. Dukhov was also named chief designer by journalist V. Orlov in his work entitled "Dukhov N.L.." The reader may therefore get the idea that he was the first. In reality he was not the first. In fact, N. Dukhov owed his appearance at the enterprise at the end of 1948 to Stalin, who understood well the significance of the chief designer and who decided that the enterprise would first and foremost have a renowned aircraft, artillery, or tank designer such as the designer-weapons specialist who had withstood numerous tests under the very difficult conditions of the Great Patriotic War.

"Why don't we have any renowned designers for this new project?" asked Stalin of V. Malyshev, "Appoint Dukhov. He is known." And so Nikolay Leonidovich Dukhov was appointed to the new sector.

No one dared anger Stalin even though the appointment came three-plus years after the beginning of the exploratory design work—after a new team of designers and researchers had already been formed under the intense working conditions, after the pilot plant was already in operation, and after the atom bomb's first subassemblies and prototypes had already been manufactured in accordance with the design documentation.

Incidentally, for the three-plus years before that time, I. Kurchatov, the future director of the entire atomic project, held another point of view regarding the selection of a director of the experimental design work. He held the well-reasoned belief that the director should be someone with a broad engineering overview, should be free of and not associated with the established dogmas in realizing designs, and should have definite experience.

In the middle of the victorious year of 1945, I. Kurchatov invited Viktor Aleksandrovich Turbiner, the head of the special design office of one Moscow aircraft plant, to his office. He had been chosen to head the future team of designers that would be charged with materializing the physicists' idea under the direction of Yu. Khariton. I. Kurchatov said "You will be presented with an interesting engineering problem. I think you are a designer who can handle the problem. Present your ideas on how to organize the development of the design of an object meeting the specified requirements. You have 2 days. We will be waiting for your ideas. Get to it." After shaking hands, they parted.

Turbiner himself tells it as follows: "From the extremely nebulous and unusual words of Kurchatov and Khariton I finally understood that they were talking about creating a domestic atomic device or bomb that should have the maximum possible caliber because that would have a direct effect on its power. The caliber was, incidentally, restricted only by the dimensions of the aircraft's bomb-bay door. Therefore, after this conversation I began to get especially interested in the dimensions of the bomb-bay doors of existing bombers that had been adapted to

conventional aerial bombs during the war years. They were the FAB-500, FAB-1000, etc. The maximum caliber of existing bombs under the bomb-bay door of the TU-4 was taken as the foundation for all subsequent design calculations. Later, while discussing organizational matters with P. Zernov, the enterprise's director, he often told me that I should not blindly listen to Yu. Khariton but should instead act on the basis of my own engineering experience and common sense, always remembering my high level of accountability for what had been done. To be honest, I did not experience any sense of fear or anxiety over the result because I already had a great deal of multifaceted experience as a designer and investigator.

The fundamental principles of the new design development and ideas regarding organizing the work were presented within the established time frame. Kurchatov liked Turbiner's proposals. "I am agreeable to working with you. You can consider yourself the winner of the contest. We gave analogous proposals to other specialists as well. You gave the best answers to the questions posed. I wish you success in the future. I will introduce you to the other participants later. Talk with Yu. Khariton about the future projects and interaction procedure," said Kurchatov in farewell.

Viktor Aleksandrovich Turbiner was born to a working family in 1910 in Dnepropetrovsk. He lost his mother early. Viktor spent entire days at the factory where his father worked as a foreman. He gained skill by taking unneeded metal scrap and making something from it. After the civil war the plant still stood. There was no work, but more often than not people could not but come to the plant and do something. Work was a necessity, and earning a wage was a matter of chance.

The father gave a great deal of his life and plant experience to his inquisitive and inventive son. And so his passion for metal was determined, and his desire to link life with engineering and machines appeared. He worked and learned at the same time. His school, a type of craft trade school, gave him knowledge in the theory and practice of metal working.

Viktor worked as a lathe operator and miller. He knew machine tools well, i.e., lathes and grinders. He visited Moscow Higher Technical School imeni Bauman, where he took correspondence courses and simultaneously worked at the plant as a worker. In 1932 he became an acting engineer-designer. He graduated from the institute with honors in 1937.

During those years, more than a few specialists, mainly from the defense industry, were sent to plants of well-known European and American firms. And so the renowned aircraft designer A. Yakovlev, the tank diesel designer V. Trashutin, and many others went on lengthy foreign work assignments.

For 6 months in 1934 the people's commissariat of the defense industry sent designer Turbiner to the famous aircraft engine plant Curtis-Wright and to the Ford Machinery Plants to receive equipment.

The out-of-town work assignment gave the young designer an opportunity to expand his horizons, gain a better understanding of the capabilities of American machine building, gain a more in-depth and better understanding of many of the unique feature and fine points of aircraft engine technologies in the United States, and become familiar with the latest technologies used in specialized manufacturing processes.

"Here is how I ended up in the United States," says Viktor Aleksandrovich. I led the design of a complicated cutting tool. The theme was being developed by a group of experienced designers. They could not reach a decision, and the machine tool created did not work.

One evening while I was alone, I tried to bring one of my own ideas to life, and I designed a new original tool that immediately performed the required operation! In the morning all the designers were impressed by how I suddenly demonstrated how I had solved the problem and by how a previously dead machine tool was working.

The plant's director G. Starchenko called me and, after talking with me for a while, decided to send me to the plants in the United States. Earlier I almost ended up in Germany in an analogous situation, but I was bypassed because of my youth.

In April 1934 a delegation of specialists traveled by international railroad car from the Kiev railroad station to Moscow. What embraces, colors, and words of welcome! And then the train departed smoothly from the platform. The immense expanses of Russia grew smaller beyond the windows. Finally there was the border. Then we traveled onward to Poland and then Germany with its exact, well-groomed little houses. Then we arrived in noisy Hamburg. The snow-white steamer Hamburg, one of the two largest in Europe, took the Soviet specialists on board. A drawn-out bass whistle sounded, and the snow-white liner departed majestically from the dock, sailing past dry cargo ships, tankers, tugboats, and yachts. Ahead lay the open sea. The course was set for faraway America.

The team leaving for the United States consisted of four specialists from various people's commissariats, three of which were later repressed. I was the youngest at the age of 24. I do not know what saved me from the same fate. Possibly it was the nobility of my comrades who did not say anything extra or bad about me. The People's Commissariat of Internal Affairs was nevertheless interested in me the whole time.

At the U.S. plants to which I was taken—and there were more than a few—I spent morning to night trying to grasp and remember everything. Later in the evening at home, I sat up into the night trying to write down what I had seen and to sketch the main concept.

I tried to accurately understand the many fine points of the American business of manufacturing engines, equipment accessories, and design and engineering documentation. The records I made and the technical documentation that I sometimes received in unique situations were a great help to me later in my work in Moscow on the Soviet 'Manhattan' project and at the office of the Privolzsk office of the Glavgorstroy [not further identified] near Moscow, when Soviet nuclear production was discussed and written in official papers.

It should be said that although the Americans were friendly toward us, they did not share their industrial secrets. They showed us their products with satisfaction, willingly demonstrated their operation, spoke of their capabilities, and judged their characteristics successfully. They tried to steer clear of questions such as how it was all done, the methods and principles used, etc. Of course that was understandable. In the United States, information that reaches a competitor costs dearly later, sharply reducing the company's dividends.

We Soviet specialists understood the Americans, but we lived in another world, and our interests were of a different sort. Our knowledge was directed not toward competition on the science and technology market but toward increasing our country's weaponry. Patriotism and a desire to see domestic machine building on a par with American machine building was what motivated us. We tried to perform our out-of-town work assignment as best and as completely as we could or, as they say, 'with something to spare.' In the United States I served as a receiver of equipment, machine tools, and tools. It was that job that enabled me to squeeze out some of the needed information. I was instructed to see and borrow everything that I could. Because I knew how to work on machine tools, I was able to do and understand a great deal on my own initiative or, as they say, just for the fun of it. I was, for example, instructed to receive a batch of shaper cutters (an important and complicated tool), and the firm Fellow Gear Shaper (in Vermont) sold them only in the form of a finished product. The firm did not sell either the technology or the tools required to manufacture cutter shapers. In order to become more familiar with the matter, I had to resort to different ruses. Usually it went something like 'I cannot sign the document, I must make an inspection.' 'What, don't you trust the firm?' 'No, I am obliged to accept your product, but I must make certain of its quality.'

In the end the American specialists would finally essentially be forced to give me all the details of the matter. It was amazing that the Americans were so hurt by any lowering of their firm's prestige that they preferred in some cases to sacrifice technical information for that very reason.

The Soviet Union was having a hard time back then. Industrialization had come. There were more than a few everyday inconveniences and problems. The Americans had a great deal of sympathy for us and showed us a great deal of hospitality. I knew English and could get along without a translator without great difficulty. I nevertheless arose at 4 A.M. and studied English pronunciation, using the books and dictionaries that I had brought with me to the United States.

Once, while proving the quality of their work, the Americans were forced to take me to a special pilot production laboratory. We passed through the shops, and they asked me not to stop. Then finally, we reached the holy of holies—the cutting tool and grinder shop. It was there that I was able to get to know the essence of the manufacturing techniques and the entire kinematics of the configuration of the machine to machine the cutting components of shaper cutters for cutting the gears of external and internal gearings. At the time, everything was a novelty for us.

I knew that a great deal of money was spent on information and that not one American firm or institution desiring to be first spared any money for information. While working in the American firms, I became certain that you can learn everything by acting curious and using your head. Later at home, I would accurately record everything I needed from my observations.

Once I traveled to the Ford Plant. I went through the shops. I saw machine tools produced by different firms. But then I saw some machine tools without any markings at all. I asked the foreman what kind of machine tools they were. "They are special machine tools produced by our firm. They were designed right here in this building," answered the foreman while pointing with his hand.

We went over into the design room. It was a big bright room where at least 200 to 300 designers were working.

I asked the designers for sketches of the machine tools that interested me. "Do you need them?" they asked. "Yes, I must admit that I do," I answered. "Then you can look at them tomorrow," they proposed. The next day a set of specially blued sketches was laid out for me. Awfully pleased with what I had obtained, I proceeded to the entrance check point. At first I was afraid that I would be detained, but everything turned out all right and I ended up outside the confines of the renowned Ford plant with my priceless burden.

It must be said that the Americans knew that the USSR was building socialism. In those years, our workers received a great deal of sympathy. Following our successes, the Americans gladly demonstrated their friendship in the most diverse circumstances and forms.

What I remember most from those days is the organizational procedure at plants in the United States. They paid special attention to specializing their business. It was the only way such high efficiency and the highest manufacturing results could be achieved. The firm Wilcox Rich, for example, produced valves for the most diverse sizes and types of engines. They produced them with quality and guaranteed lives and in gigantic quantities that would fill half the world. This same approach to specialization was used in our 'Manhattan' project. I

considered the unit-by-unit method of developing the designs of the RDS-1 to be extremely important. I personally did the general overall layout and instructed various departments and subdepartments specializing in the further work required to complete the development of the individual subassemblies and components. And so we developed our own development techniques and methods. As far as I know, this same approach has been maintained in the creation of other prototypes.

The out-of-town work assignment had been completed, and I was preparing to leave when I suddenly received a phone call from the Amtorg [not further identified] asking me to stay an additional half a year. The year 1934 passed. I will admit that I longed unbearably to go home to the Soviet Union, and I refused. I had already acquired important experience, and my head was full of plans. But it would still be a long time before my fate as a participant in the Soviet 'Manhattan' project would befall me and I would achieve the good luck of a designer who has achieved his result. All that lay ahead....

I returned home from the United States of America on the famed steamer Queen Mary. A multitongue noise existed in the port of New York. There were exclamations of welcome, words of farewell. This time the flowers were not for me; I was, nevertheless, excited by the rising feeling of departure for my homeland.

Amidst the mottled and multifaceted crowd I stood on the steamer's stern, keeping my glance fixed on the shores of the United States of America that were becoming ever-smaller in the distance. The country's symbol, the Statue of Liberty, which was a gift from the French government to America, slowly sunk beyond the stern in the mist of the sea. The country of Columbus and of great possibilities, where there is still something to see and something to learn, lay behind.

The Atlantic Ocean was calm and endless. The broad foamy wake of the ship stretched far behind the stern. The clamorous sea gulls were quickly left behind. The liner traveled to London.

In the capital of "misty Albion" I transferred to the Soviet steam Feliks Dzerzhinskiy. The long voyage was inexorably coming to an end.

Leningrad is encountered like all other ports of the world. There is the noise and the colors. You tear slightly and puff out your cheeks when meeting someone. It is a spiritual orchestra. The last leg of my travels had been completed. The nearest express took me home to the capital.

My relatives, close friends, and simple acquaintances all listened with interest to my my stories about the far-off country and its achievements in technology.

Many read the famous book by N. Smelyakov "Delovaya Amerika" (Businesslike America) that was published a good deal after the war and that summarized the author's personal impressions. I perceived much of the same, although perhaps less systematically (I was 24 while on my assignment in America). The notes I made were of a more technical and specialized nature. They were an attempt to delve into the depths of the capabilities of American technology. But the book in question can, if you please, be seen as my personal recollections of what I saw [recalled Viktor Aleksandrovich not without sadness]. And after my return to the plant, my colleagues, comrades, and the management treated me well and in a friendly manner. Once again I threw myself into my work and into the exuberant plant life. Motors, fittings, and sketches filled all my time.

The new wartime life inexorably drew near. The year 1941 caught many of us by surprise. Despite the newspapers of 1939 and 1940 and the totally alarming communications, thoughts of war were still far away. In truth, it was understood that if there were to be a war it would be very difficult. And then unexpectedly the day 22 June 1941 arrived. It was noon on that memorable day. V. Molotov's speech was on the radio. Things became alarming in Moscow. There were fewer people on the streets. Many soldiers were moving around in groups, on foot, in cars, and in trucks. The barrage balloons appeared. In those days of difficulty for Moscow when the fascists seemed closer every day and the bombings of the capital were becoming more frequent, I worked as the director of the special equipment design office. I went to the military registration and enlistment office to volunteer for the front. I thought that they would take a healthy adult like me. But I was told that they had individuals to fight and that workers were needed at the rear. Without the rear there would be nothing to fight with at the front. I was told to go and work. And so I went and worked—sometimes without sleep or rest. It was then that the slogan "Everything for the front! Everything for victory! was born and lived. Those words lived in each of us throughout the difficult war years.

The day 14 October 1941 was a critical day for Moscow's defense. Moscow was deserted. Those who remained worked indefatigably. We lived at the plant for weeks at a time. We went home only rarely—indeed just to bathe and sleep. My war years were devoted to developing and finalizing the development of special tooling and machine tools for equipment to be used in the manufacture of aircraft engines, primarily to manufacture the engines designed by Mikulin, etc. I came to know what hunger was. Those years will always remain in my memory.

The most difficult years of the war had passed. The battles near Moscow and in Stalingrad and the Kursk bulge were behind us. There had been the forced crossing of the Dnepr. Each day Moscow saluted our troops' victories. The voice of Yuriy Levitan resounded throughout the country from Shabolovka, exciting and raising the mood of the Soviet people. Victory was drawing nearer and with it Potsdam. Everyone thought that there would never be another big war. Another war seemed monsterous....

But not even a year passed before Great Britain's former prime minister W. Churchill presented his wildly renowned speech at Fulton, marking the beginning of the Cold War. No one had foreseen this.

A historic meeting of the heads of state had been held in Potsdam. At the meeting Truman convinced Stalin that the American atom bomb had been tested successfully and that the Manhattan project had been completed.

As American physicist R. Lapp wrote of the event, "According to witnesses, President Truman consulted with his advisers and decided to let Stalin in on the secret. While walking from one end of the meeting room to the other, he informed Stalin. The message did not make any special impression on the Soviet leader. He received it rather indifferently. As Truman himself said later, he believed that Stalin was incapable of understanding the significance of the message." Eagerly watching Stalin's reaction, Churchill also concluded that Stalin most likely did not understand the significance of the fact. But in fact, as soon as he returned from the meeting, the generalissimo rushed to Molotov and said "Kurchatov must be hurried along." R. Lapp went on to write, "We have only just discovered that Stalin had been informed of our success in the area of creating an atom bomb long before the said communication."

On 6 November 1947 Soviet Minister of Foreign Affairs V. Molotov made the announcement that "the secret of the atom bomb does not exist." The conclusion drawn from this announcement had to be that the USSR has nuclear weaponry.

On 3 September 1949 an American B-29 bomber completing an ordinary patrol flight in the region of the Pacific Ocean at the borders of the USSR unexpectedly detected the traces of tests of the Soviet atom bomb in a routine collection of radiochemical samples....

On 25 September 1949 the first page of the newspaper PRAVDA ran the following TASS communication: "On 23 September President Truman announced that according to U.S. government data, the USSR conducted a nuclear explosion sometime during the past few weeks." An analogous announcement was made by the English and Canadian governments. Immediately following publication of these announcements in the American, English, and Canadian press, as well as in the press of a number of other countries, numerous remarks appeared that spread alarm in broad social circles.

In view of what happened, TASS was authorized to announce the following: It is well known that large-scale construction projects, i.e., hydroelectric generating stations, mines, canals, and roads, that require large explosions using the latest explosives are under way in the Soviet Union. Because these explosions have occurred and are continuing to occur rather frequently in various regions throughout the country, it is possible that they may attract attention outside the Soviet Union's borders.

As far as the production of nuclear power was concerned, TASS considers it necessary to mention that as far back as in November 1947 USSR Minister of Foreign Affairs V. Molotov made an announcement concerning the secret of the atom bomb, saying that "this secret has long ceased to exist."

This announcement meant that the Soviet Union had already uncovered the secret of nuclear weapons and had such weapons at its disposal. The scientific circles of the United States of America took Molotov's announcement as a bluff, assuming that the Russians could not have had nuclear weapons before 1952-1955. They were mistaken, however, because the Soviet Union had the secret of nuclear weaponry back in 1947.

As far as the alarm that this fact caused in selected foreign circles is concerned, there was no basis for it whatsoever.

It should be said that despite its possession of nuclear weaponry, the Soviet government always has and will continue to hold steadfast to its old position of an unconditional ban on the use of nuclear weapons.

In relation to nuclear weapons testing, it may be said that testing will be necessary to make certain that the decisions regarding the ban on the production of atomic weapons is carried out.

Such was the full text of the aforesaid document.

Photo Captions [photos not reproduced]

1. p. 38: Academicians Kurchatov and Yu. Khariton, creators of the Soviet atom bomb.

2. p. 39: V. Turbiner, first designer of the Soviet atom bomb: "I understood that an atom bomb was what was being discussed even though the word 'bomb' was never mentioned. How much time did we spend: Yu. KHariton answered that we gave it 5 years in all. During that time we were obliged to keep to ourselves."

[Part 2. Dec 91, pp 34-38]

[Text] By mutual agreement we [Turbiner and his associates] continued to work on our previous projects, naturally not permitting any conversations on the new matter with outsiders. Yu.B. (Khariton) told me more than once that we were still not officially organized but that in the meantime we would continue to work where we had worked. Aware of the secrecy of the project, I never asked anyone anything but instead always thought about about how to best solve the problem that had been formulated. Yu.B. did not give me any technical specifications or any special clarifications. I had already been given permission to become familiar with the materials and to learn how atom bombs were created and designed. A great deal was new to me. I had to make sense of everything anew. A great deal related to the new development had accumulated and sunk in my head.

Worst of all, I considered myself the leading developer, even though I was the sole designer. At the time, the project was so secret that I had no one with whom to consult on design and engineering problems. And then the design of the atom bomb was shown to only a few individuals and specialists. No one, with the exception of several directors, was authorized to enter my office at Ryazanka in Moscow (now the former building of the All-Union Central Soviet of Trade Unions [VTsSPS]) after the first organizational measures had been announced. I completed the overall design layout for the first Soviet atom bomb.

A short while later I became acquainted with P. Zernov, who was deputy minister of transport machine building at the time. He had been instructed to head the facility administration, which is to say, the entire enterprise. He was the Soviet "Groves." Somewhat later Yu.B. introduced me to N. Terletskiy, M. Yakovlev, etc., with whom I was to work on various directions of the design work. These comrades were the first to begin developing the design of the charge, but I first had to give them specific design assignments. I was also introduced to M. Adaskin, the institute's chief engineer, who had been instructed to oversee the overall course of the work. He was administration in its pure form, representing the organization side of the work rather than its scientific or design backbone. The scientific research on the most important gas dynamics problems was led by doctor of sciences Ye. Zavoyskiy, a talented person who had graduated from Kazan University at that very time and later became an academician. V. Tsukerman and L. Altshuler joined the project somewhat later and worked on recording the high-speed processes.

All of that happened later. At the time, which is to say in 1945, Yu. Khariton asked me to complete the design of a first approximation as a demonstration for the country's highest leadership. For practical purposes, I had to hold more than one job because no official decisions had yet been made. By that time I had already gathered a great many useful materials and, as it seemed to me, thought through a great deal.

At the very beginning of 1946 I [Turbiner] made a model of the product on a 1:10 scale. For practical purposes, it was the first conceptual design of the Soviet atom bomb. Khariton and Zernov showed the design to Stalin and Berea. Along with the model, the design also contained a general layout diagram with the required dimensions and cross sections in color.

It should be said that the design contained not only the charge but also an aerial bomb adapted for discharge from series-produced Tu-4 bombers. We are thus speaking not only of a nuclear charge but also about a product that was an entire bomb. The product was built in accordance with the modular (or unit) principle, which made it possible to disconnect and demonstrate individual subassemblies, such as the automatic detonation devices, as well as to manufacture individual special complete subassembly/units. The design was exquisite from an engineering standpoint, convenient to operate, and technologically feasible to manufacture. In view of the established secrecy regimen, V. Turbiner completed the design and construction of the bomb alone. The other designers involved in the project, i.e., N. Terletskiy, M. Yakovlev, and N. Maslov, handled individual parts and were unaware of the overall layout diagram.

In May 1946 Khariton and Zernov informed me [Turbiner] that they were going to show the design in the Kremlin. Finally, they got an idea of the project in the Kremlin. I asked Yu.B. whether there were any comments. He replied, "No, there were no comments. Everything proceeded normally. The work was approved. Handle the matter as you have been. A CPSU Central Committee and USSR Council of Ministers decree will soon be issued, and we will include you and the other specialists needed for the development in a new collective."

In fact, the long-awaited government decree was issued a month late on 27 June 1946. After yet another month on 25 July, Khariton wrote general technical specifications for the development of an atom bomb. The specifications were quickly sent to the USSR Council of Ministers for presentation to Stalin. The specifications were shown to practically no one, including the designer-developers.

On the basis of the issued enterprise decree PR. N 3/k dated 1 August 1946 (VNIIEF archive reference N 2022-T/30 dated 28 December 1984), Viktor Aleksandrovich Turbiner was assigned to staff KB-11 as the head of the scientific design sector and was temporarily relieved of his previous duties at the plant in Moscow.

Specifically, the government decree dated 27 June 1946 also stipulated the following:

—shipment of 104 metal-cutting machine tools to the enterprise in July;

—shipment of 100 telephones;

—shipment of 300 gasoline tanks;

—allocation of $5,000 in 1946-1947 for physics, chemistry, mathematics, and engineering books and journals for creation of a library.

The government instructed the Ministry of Trade to supply the enterprise with everything it needed. Specifically, the daily per-worker norm for products was as follows:

bread, 400 g; cereals, 20 g; pasta, 50 g; potatoes, 500 g; cabbage, 200 g; sugar, 80 g; meat, 350 g; dried fruits, 20 g; milk, 200 g; cheese, 20 g; cottage cheese, 20 g.

By the end of 1947 a mock-up of the atom bomb had already been constructed at the facility's pilot plant. The model was made of metal on a 1:10 scale and represented

the product in its true colors. The mock-up demonstrated the product's configuration even more graphically than the first model sketch on a 1:10 scale that was shown in 1946 [recalls Turbiner].

This second model in metal was intended as a demonstration for Stalin. N. Pavlov, an envoy of the Council of Ministers, warned me [Turbiner] that the model should have no sharp edges that could scratch and that the paints applied to the model be unscented and mentioned a few other precautions as well. The model was made in accordance with all of the conditions set and brought to the designated place.

Just as after the first (paper) model had been demonstrated to Stalin, Yu. Khariton did not relay any comments comments regarding the design, technology, or organization, and I continued working on creating the products with my previous effort and direction.

I feverishly accumulated scientific-technical and information materials for the rest of the work. While drawing up the overall layout, I was, for practical purposes, specifying the face of the future design. To avoid making any mistakes, I instructed my assistants (comrades Terletskiy, Yakovlev, and Maslov) to work out the individual subassemblies painstakingly and sometimes in more than one version. There was a great deal to consider when making the design decisions, which were still based primarily on existing general engineering methods. The need for new approaches, techniques, and methods of making such decisions had also become evident, however. Indeed, the structure was to include materials that were being used for the first time, whose properties were unstudied, and whose behavior was unpredictable. How the already-familiar materials would behave in combination with radioactive, etc., materials was also totally unclear. There were a whole set of questions.

The project had grown larger. It should be said that the ration system of distributing products was still in effect at the time (it was finally stopped in December 1947). We were well supplied, however. I did not even always have time to "get goods issued to me" as the Muscovites used to say back then. But I was no longer in need of anything.

There were an enormous amount of problems. I began adding more staff to solve them, and the organization of our team of designers began.

I. Terletskiy became the head of the department responsible for the charge and its components. N. Maslov became director of the department of configuration and general forms, and N. Shvilkin became the head of the department of basic equipment and accessories for assembling the charge.

As director of the scientific-design sector, I always had the utmost respect for V. Grechishnik, the talented designer of aircraft and tank diesels, who was at the newly organized nuclear facility. We both felt that technology dictates the time for introducing a design. Grechishnikov proudly gave himself to his work. He was slated to be appointed head of the department of charges.

Doctor V. Tsukerman tells the following story about him. When the first product was assembled, problems arose with the assembly of the multicomponent structure. Because he was so slender, he [Grechishnikov] crawled inside the product and pushed the elements of the charge against one another by bracing his hands and legs against the casing walls.

Kh. Kostanyan was Zernov's supply assistant. He played a similar part in the developments of S. Kocyharyanets, who was appointed deputy to I. Dukhov after my departure. V. Zuyevskiy joined the work a bit later as head of the automatic devices laboratory. With a single exception, all of the individuals mentioned later became the main designers of the sector!

By order of the highest department administration, P. Zernov, head of the enterprise (which had been named KB-11 [Design Office-11]), Yu. Khariton, head of the design office, and V. Turbiner, head of the design office's scientific-design sector, all moved from Moscow to the site of the facility (as the associates then called it).[1]

"The railroad brought us to the Sh. station, and then we traveled by car to the site," recalls Viktor Aleksandrovich, "to the tsar's cloister." It is curious that those lands were mentioned in the personal diary of the last tsar Nicholas II, who wrote the following:

'19 July—Saturday. In the morning there were the usual things. After breakfast I called Nikolasha to me and told him he had been appointed Supreme Commander right before my entry into the army.

'Aliks and I came to the Diveyevsk Oblast. I took a walk with the children. At 605 I rode to the night service. When I returned I found out that Germany had declared war....'

The forest reserve stood still. A fluffy snow sparkled along the roads. The frost was getting harder. After several hours of travel we reached it—the site where the new city, the city of the nuclear specialists, would be. Nevertheless, there was no sense of the historical nature of the events. My [Turbiner] burning desire was to finish the job assigned as fast and best as possible. Not to let them down. Yu.B. also acted without ceremony. He gave a great deal of his effort and time, and each day he solved many problems, sometimes far removed from the physics. All of those participating in the work were preoccupied and understood the seriousness of the matter and their accountability for the anticipated result.

The personnel department continued to send design personnel whom I distributed throughout the departments. Upon our arrival, we (Yu. Khariton and I [Turbiner]) each settled into a separate Finnish home. At the time, there were still just five of us. Materials for

construction of the lodging and production facilities were arriving continuously. The regime services stormed around, jealously guarding the state secrets. God forbid you failed to surrender documents on time, have them stamped, or show them to someone. The regime! The kinds of results that would come from such numerous efforts! More than a few of the most banal problems arose in organizing the workstations, supply, feeding, medical care, etc. They had to be solved just as quickly as the basic scientific and engineering problems. And not one director was free from having to solve these problems.

Young specialists started staying at the nuclear facility. They immediately began receiving a higher wage. The closed quarters, the lack of any special entertainment, and the shortage of female companionship initially made them thirst for alcohol. All occasions were a reason for drinking, which often led to amusing incidents.

It is known that a portion of the structures at the nuclear facility were built like prisons. The construction site was chained, a barbed wire fence was erected, and sentry towers were raised at the corners. The prisoners arrived for work in the morning and got down to work after roll call. In the evening both the prisoners and the guards abandoned the construction.

One time a specialist who lived in the dormitory across from the construction site got drunk and wandered home late in the evening. In the dusk he wandered into the wide-open gates of the construction site and fell asleep peacefully. And in the morning when the crew of prisoners had begun working, the young specialist, who looked little different from the prisoners in his suit, came to his senses and tried to leave the chained area. A guard aimed his automatic at the specialist and ordered him to get to work. "I don't work here," the young specialist tried to protest. But only after repeated shouting by the prisoners and the cleaning woman who worked at the dormitory across the way and who recognized the lodger was he given his freedom.

This story amused all the associates for a long time.

The new nuclear enterprise was created on the territory of the Sarovskiy monastery. Seraph Sarovskiy and Sergey Radonezhskiy were both well known in Rus. Both were acknowledged saints from their birth. Each year pilgrims were drawn to the holy places, including the fountain of miracles located on the monastery's grounds. But the creation of the nuclear facility marked the beginning of a new stage: A decision was made to enclose the enterprise's entire territory inside barbed wire and to guard it all by divisions of domestic troops of the USSR Ministry of internal affairs. Their motto was "Running a sentry box is a military task." Many buildings, temples, and the fountain of miracles thus ended up inside the "zone." At a number of sites the pilgrims tore through the barbed wire with their bare hands, trying to complete their pilgrimage to the holy places. But they were powerless against the armed guard.

Construction of the facility continued. The spring was covered over with concrete, several temples were blown up by G. Lominskiy's demolition squad—a fact he was proud of.

The first Soviet nuclear facility had been built without God's blessing. Hardly any of those who gave the orders gave any thought to the fact that Rus was losing its historic relics. In our time we have been able to resurrect the spring, but the temples have been lost forever.

Work in the administration building finally began in February 1947. In the old days, the building had been intended to house the tsar's family and his servants. But because no large equipment was required for our production tasks, it was still suitable for use. It should be noted that even though the building was reoutfitted and remodeled more than once, it fulfilled its function of an administration building for the enterprise's management for a long time.

Now, in our day, a memorial board with bas-relief and an inscription hangs at the building's entrance. The inscription reads "In this building in 1947-1950 there worked the first director of the enterprise, two-time Hero of Socialist Labor, and USSR State Prize Winner Pavel Mikhaylovich Zernov." This is the very same Zernov who Berea called to his enormous and pompous office in Lubyanka that looked out onto the site shortly before the explosion, when the commission was working at the utmost speed to evaluate the activity and anticipated (according to the commission's thinking) an unsuccessful result of the development. Berea chastised Zernov for conniving with the scientists and designers who he said were hampering this most important assignment of the party, the government, and comrade Stalin himself by his [Zernov's] inaction and intentional dragging out of the work. Incensed, Berea stamped his feet on the parquet.

While listening to him, Zernov became increasingly flushed. He knew how intensely the people were working—sometimes working nights and not leaving their workplace until the specified job had been completed. A great deal was done for the common success. Rest was provided on the territory of the pioneer camp rather than in the resorts of the azure Crimea or close to the Narzan streams of the abundant Caucases.

And then, unable to restrain himself, Zernov grabbed a heavy paperweight from the table and waved it at the shouting babbler. Suddenly two bodyguards who Berea had called by pressing a secret button appeared at the office threshold and silently walked over to Zernov. In a minute, already recovered from his lack of restraint, Berea waved them off with his hand and said "Go for now." Then he added sinisterly, "We will await your result."

Academician Lev Andreyevich Artsimovich told his close friend how more than once he heard Berea say "we will eventually part company with the nuclear specialists. But we need them for now."

In his article "Reading Letters About Science," Professor V. Frenkel recalls P. Kapitsa's statement to the effect that "after its (the atom bomb's) tests had been completed successfully, the question of prizes for the scientists arose. Berea was also in charge of that. The nomination of one of the project participants was being considered. He had been nominated for the title Hero of Socialist Labor. Berea did not support the nomination. Turning to his assistant, he asked, "What was written for him in the event of failure? Shooting?" "No, comrade Berea, not shooting." "Well, if not shooting, then the Lenin Order will suffice for him."

Such was the situation. The incident described is possibly what kept Zernov, who did so much to organize the project, from receiving any reward for the first nuclear experiment on 29 August 1949.

But there is another side. V. Zhuchikhin, then engineer-investigator, said the following: "My job was to develop subassemblies and components from explosives for the main nuclear charge. The job was unconventional, entirely new, and complicated. Once, I was idling around the work site with a fellow worker as usual. The forest encircled us. It was sunny. It was a usual workday.

"Beyond me I heard the squeal of a car's brakes. I turned around and saw that a Ministry of State Security [MGB] lieutenant in a black leather jacket was moving toward me without hurrying.

'Are you Zhuchikhin?' he asked as he approached.

'Yes,' I answered.

'Viktor Ivanovich?' he asked.

'In the flesh.' I answered, 'But what is the problem?,' I asked.

'I am taking you to the general.'

"I thought that he must mean Zernov and wondered why he needed me. But perhaps that wasn't it. Had I committed any sins? Such were the heavy thoughts that nagged in my head. 'We are going in the general's car,' I thought. 'There must be some hidden design.'

"The lieutenant touched me on the shoulder, 'Let's go. They are waiting.'

"We got into the ZIM [car] and hurried. The wind glided across my face. I felt neither space nor time.

"We stopped at a red brick building.

"It was the administration building. We went to the second floor along a carpeted path. In the big office sat a pair of generals: P. Zernov, director of the facility, and N. Pavlov, envoy of the USSR Council of Ministers.

"'Viktor Ivanovich,' said Zernov as he turned to me, 'a package has come for you from Moscow. Take it. It is for you personally.'

"As if in a fog, I took the package and grew cold. I read, 'Dear Viktor Ivanovich! I heartily congratulate you on your receipt of the Order of Lenin and award you the Stalin Prize. Respectfully, I. Stalin.'

"I looked at the smiling generals dumbfoundedly. I left the room after asking permission, not feeling my legs."

Many problems arose once we began the process of working according to a concrete design [Turbiner continues], and I had to solve them. A large-diameter sphere had to be ordered from a plant in Gorkiy. The purpose of the work was to check to see whether domestic equipment would be able to achieve the precision required for correct assembly. There were more than a few other analogous jobs. We had to make sure that all of the components could result in a correctly joined and assembled product and that they conformed to the layout decisions that had been made. As was said above, the physicists did not furnish the designers with the technical specifications corresponding to the design. I worked on a general layout diagram and refined it during the course of the work. A designer's task is to give the diagram a concrete form that could be developed to enable an actual product to be manufactured in metal. Neither did the physicists furnish any other documents to follow as the charge was designed. Under these conditions, the designer-developer was faced with a big job in comprehending and carrying out his job. A great deal of common sense, engineering intuition, and (at times) business sense was required to achieve a good result. The result would be acknowledged not only by the plant's process engineers and workers but also (primarily) by the physicists and gas dynamics specialists, which is to say by those responsible for the scientific side of the problem. To have one's work be up to par with respect to a whole set of problems is, you will agree, far from simple. But we had nowhere to turn. We mulled over all these problems, many of which were classified as secret. The regime and its service did not provide us with anyone to help answer our questions but instead acted quite to the contrary. Formalism was smothering us, but we had to reckon with it. And our work moved forward.

I fashioned an overall view of the product on a 1:1 scale, ordered a huge blackboard, and put two pieces of chalk out. Everything came together on paper ideally. Even though several departments had worked on the design, everything fit together. The experience that had been gained had helped. Without it, it would have hardly been possible to complete all of the design and planning work in so short a time and with such quality. More than once Zernov said to me confidently, "Work and do everything as you see fit yourself. Don't listen to anyone, including Yu.B. [Khariton]. Think for yourself. Know that you are the one expected to complete the design and manufacture." And that is just how I understood the project. I did what was necessary, did the calculations, formulated the tests and engineering experiments, and then developed the sketches and handled the manufacture of the prototypes and manufacturing accessories to produce the future product.

Many difficulties arose with the overall layout of the bomb. It was, for example, impossible to achieve a sufficient aerial bomb length because the pressure shifted too much in front of the center. To give the entire product the specified stability, brake platforms were provided at the ends of the tail vanes in accordance with the advice of Academician S. Khristianovich after wind tunnel testing at the Central Aerodynamics Institute imeni N.Ye. Zhukovskiy [TsAGI]. We were able to make the bomb shorter so that it could be gotten in and out of the bomb-bay doors normally. This was important. There were other design complications as well. P. Zernov, who had himself come from the Ministry of Transport Machine Building, very much wanted to include his own specialists in the development of the first Soviet atom bomb. But how? He proposed a simple way out, trying to force me to make a pressure system to eliminate the protection stages and a pressure instrument to fire the charge. Even though the sensor was still suitable for the former, there was a large spread of parameters for the latter. I had the necessary consultations with Academician Shuleykin at the Hydrometeorology Service Institute. I was more inclined to use an aircraft radio altimeter, but it turned out to be less well suited. So I decided to use both instruments, thereby providing the maximum reliability through their redundancy.

A total of five full-scale models and several test flights of an An-2 aircraft were needed for the check aeroballistic tests and to check the parameters of the trajectories and the sensors used to fire a standard product. They provided useful material for a preliminary estimate.

The developers also had a Douglas (B-47) aircraft at their disposal for quick connections, and we used it extensively.

The usual design practices followed when creating designs and design documentation took 1.5 to 2 years. The second stage of the work required the same amount of time to create the special manufacturing accessories and equipment if all was to be done sequentially. And this was a reliable practice. But where was the time to come from? To speed up the project I felt it extremely necessary to create a department to develop the manufacturing equipment that would be attached to the scientific design sector. From what I knew about the design process and in consideration of the American experience, I considered it important that the work to create the basic design and to develop the accessories required to manufacture it be conducted in parallel with one another. I was deeply convinced that such an approach would enable us to save years. It was very important to make the simplest possible manufacturing accessories for the basic design. I never forgot the words of the famous Henry Ford: "My goal is simplicity." American designers have the following to say on the subject: "He is not smart enough to make simple things."

I felt it advisable to appoint N. Shvilkin head of the manufacturing accessories department. He was deeply aware that he had been given one of the main departments. Unfortunately, all of the departments already had their own worthy directors. It should be said that N. Shvilkin was a talented engineer. In his own time he was a brilliant student at Moscow Higher Technical School imeni Bauman and he handled practical work beautifully. And time had shown that he handled the job of having a department under his direction beautifully and won valuable time.

Terletskiy and I developed the design of the casting molds for casting the elements of the spherical charge. The casting molds were ordered and manufactured in Gorkiy at a plant directed by A. Yelyan. The Gorkiy craftsmen manufactured the molds, which were complex from a technological standpoint, quickly and beautifully under the painstaking personal control of A. Yelyan. The molds were delivered in the required time, and all the complicated components were assembled without any adjustment. These measures enabled us to save a great deal of time—1.5 to 2 years.

In addition to everything else, the project involved a great many fine points whose handling was very important. The vertical boring and turning mill that I ordered (P. Zernov bought it in England), coupled with the special manufacturing accessories designed in N. Shvilkin's and N. Terletskiy's departments, made it possible to machine and assemble the spheres and hemispheres with great precision and great speed.

The progressive development of the designs of the manufacturing accessories and their actual manufacture in a pilot production process under the direction of A. Bessarabenko also gained us a great deal of time.

As a designer looking forward to the future design of large product components, I issued technical specifications to N. Shvilkin's design department to design adjustable accessories. They were manufactured before the shop sketches of the main product itself had been completed.

The successful course of the technological preparation of production for which I (and neither Yu. Khariton nor P. Zernov) was completely responsible also instilled me with the good spirits and confidence of success [recalls Turbiner].

Footnote

1. This city of the nuclear specialists, where the first Soviet atom bomb was born, was described by reporter V. Umnov in the 25 November 90 (No. 271) issue of KOMSOMOLSKAYA PRAVDA in an article entitled "Silent People Live Here". It was also described by reporter Yu. Dmitriyev in the 28 Nov 90 (No. 275) issue of TRUDA in an article entitled "Get Acquainted With Arzamas-16."

Photo Captions [photos not reproduced]

1. p 35 (upper right): View of the Serafim-deveyevskiy Monastary, on whose territory the nuclear enterprise was created. Fragment of an old engraving.

2. p 35 (bottom): Academicians I. Kurchatov and Yu. Khariton with workers from one of the nuclear enterprises.

3. p 40: Uspenskiy Sobor [Cathedral of the Assumption], where the relics of the Reverend Seraph were kept. It was blown up in 1947.

[Part 3. Jan 92, pp 35-37]

[Text] I understood [recalls Viktor Aleksandrovich] my total independence in embodying what the physicists had given me in metal. And I fully understood the big responsibility that I had been given and my accountability for the end result. During the course of the work, I became entirely certain that the designers, process engineers, and production specialists would not let me down in the matter of preparing and conducting the first test of the Soviet atom bomb. We had done all our work conscientiously and at a high professional level.

I did not tolerate any hustle or bustle in the work. Five to 10 days before the coming month, A. Bessarabenko would visit the designers, usually with the chief engineer from the pilot production plant. And we would compile the production plans together. At the same time, we would solve the most pressing problems and discuss our future options.

Thanks to such work, the first components manufactured in metal at the pilot production plant and the first completed subassemblies began to appear by the middle of 1947. But we lacked sufficient facilities for success. Other enterprises (primarily through P. Zernov) had to be included in the project. In Gorkiy (now Nizhniy Novgorod) there was A. Yelyan's aircraft plant, where components and selected models of the main product were manufactured in accordance with our design documentation. When this work had been completed, we began the plant tests. It was important to determine the aeroballistic characteristics and capabilities of the military product. Although the design of the atom bomb's casing borrowed a great deal from the design of conventional bombs (the FAB-500, FAB-1000, etc.), it had more than a few of its own distinctions.

Even the casing itself made it possible to access the bomb's vital parts for inspection purposes and final discharge of the charge without dismantling, as well as to test the automatic detonation equipment and support systems and evaluate the special equipment assemblies and activation equipment (which was being used for the first time).

Radio altimeters were produced for the USSR People's Commissariat of the Aviation Industry [NKAP] in Gorkiy. They began producing them for us as well. The designer Skibarko was even specially assigned to the job and was later promoted to director as a result. At the time he worked in accordance with our technical specifications. The technical specifications called for activating the automatic detonation device at the optimal altitude. Strictly speaking, the telemetric testing equipment for practical use under flight conditions did not exist at the time. It had to be created from scratch at the same time.

That work was conducted in the laboratories of M. Yakovlev, V. Zuyevskiy, and V. Vasilyev, who were all specialists in this new area of technology. It fell upon these same laboratories to develop the entire telemetry system to control the bomb's detonation.

Moreover, we made several full-scale models that were suspended under an aircraft, and we worked out the design, the procedure for servicing it during operation, and the ballistics of its trajectory. The necessary aerodynamic wind tunnel testings were conducted at the Central Aerodynamics Institute imeni N. Ye. Zhukovskiy [TsAGI] under S. Khristianovih's direction. A picture of the design's flight was obtained along with the necessary data confirming the calculated engineering parameters. I either personally handled or else directed all of the scientific-technical operations, contacts, joint work, as well as discussion and evaluation of the results. It was natural that I do this because I was accountable for the final result. Only the necessary administrative measures were left to Zernov, and he handled them magnificantly.

We thus sequentially worked out the product's design and tested it successfully on 29 August 49. The approach of unit-by-unit testing, assembly, and service of the design, which I adopted and introduced, had proved fully justified. The automatic devices, high-altitude detonation system, etc., all checked out. The charge with its fissionable materials could not be held at the plant or preparation site for long. The product was designed so that one man could place the charge of fissionable material inside an already-suspended bomb in several minutes.

Ensuring the synchronous detonation of the nuclear charge was a separate and important design task. Yu. Khariton continued to voice his concern that the detonation devices would activate at different times exceeding the specified allowance. We therefore experimented constantly to ensure that everything would turn out stably. The first fuze specialists, namely, M. Puzyrev, and later A. Pavlov and V. Lilye, appeared in my facility. But before then, I had been forced to develop the design of the fuzes and the necessary sketches, which were later used as a basis for manufacturing the first prototypes at the plant in Ivanovo.

The flight tests conducted to test the automatic detonation devices were first conducted at the Air Force test area by General V. Chernorez in the Crimea. For many

long years the test area served the purpose of perfecting bomb prototypes and creating the latest bombs.

Further thinking about the future of nuclear weaponry [continues Turbiner] led me to conclude that using them not in their bomb version but rather in an aircraft shell version of the FAU-2 type would be highly feasible and effective. After considering all aspects of the concept, I developed a conceptual design and schematic of a warhead for the Soviet FAU-2 and showed them to General A.A. Aleksandrov, head of the ministry's Main Administration of Experimental Designs. He liked the concept a great deal. (It should be said that Aleksandrov and Zernov had a high opinion of Turbiner's activity but that they did not give their approval to the project at the time. Only much later, after about 10 years, did the first winged rockets with a nuclear charge appear in the country's arsenal).

In general it was striking that there were never any comments or criticism of the engineering or appearance of the design or of the organization of the design work from either Yu. Khariton or from the administrator P. Zernov [recalls Turbiner]. Nor were there any comments regarding the tempo of the design or production operations. Everything was completed quickly, on time, and precisely in accordance with the intensive plans. Even though the work was very difficult, it was satisfying and I enjoyed it all. My design decisions were not revised, and everything went according to my preliminary thoughts.

True, they sent us good designers. That is very important. There was only one case during the development process (which has been mentioned) where an addition was made to the design of the main charge after the receipt of a communication from Yu. Khariton saying that the a small number of elementary particles would, according to the researchers, move from the central part of the charge and that it would be advisable to add an additional screening jacket. We fashioned a thin jacket in the form of a shell encompassing the center part. That was still in the first stage and did not interfere with the course of the design process.

The most renowned scientists, namely, N. Semenov, A. Aleksandrov, I. Tamm, etc., came to the facility. But the designs being formulated were not shown to anyone.

Once P. Andropov (a member of the commission) visited the design sector departments and was introduced to me by P. Zernov as minister of geology and deputy head of the KGB. I told him about the product's configuration briefly (I had already prepared an overall view of the product with full-scale cross sections). The first prototypes of the product were already almost ready at the pilot production plant. We exchanged pleasantries and that was all. He mentioned that he knew my uncle was a coal dealer and reassured me that this was a positive fact.

Many problems were worked out and solved during the creation of the structure to suspend and transport the bomb in A. Tupolev's aircraft. While readying the aircraft for the nuclear experiment, we should have thought about how the shock wave from the explosion would affect the machine and about how the materials of which the aircraft was made would behave in a field of light.

Our material strength engineers solved the first problem quickly. The calculations showed that the machine's strength was sufficient and that no reinforcement was necessary.

The problem of the light field was more complicated. No one in Russia had done such research. There was no one whose results could be borrowed. The decision was made to experiment. Tupolev asked the antiaircraft gunners for a high-power projector. We mounted it at one end of a long corridor and placed test specimens of the materials at the other end. We focused the projector's beam on them. We turned it on and waited a moment. Suddenly there was a cloud of smoke from the surface....

These tests convinced us of the need to paint all of the dark spots of the aircraft's lower surface, all the radomes, and the antenna columns with white nitrocellulose enamel paint, as well as to mount protective metal curtains in front of all the crew members.

Andrey Nikolayevich Tupolev himself and his specialists A. Arkhangelsk and L. Kerber expressed a great deal of interest in this work and participated personally in a discussion with me and other the designers and developers of the nuclear device. He trusted our joint work. It is curious that no matter what the institute, design office, or plant, all doors opened quickly when we appeared, and the bureaucratic barriers were removed. Everything was done quickly and on time. It was a miracle. Many scientists wanted to participate in the new project. The academician and mathematician Lavrentyev asked more than once if he could be useful.

By November 1948 practically everything was ready. The design and technological decisions had been made and tested both theoretically and experimentally. The manufacturing techniques had been tested, the equipment had been selected, and the required accessories had been manufactured. Personnel appeared and gained new experience. The first actual test prototypes of the bomb's subassemblies and components had been produced. The main work had been completed. There was no longer anything that could stop the process of the creation of the first Soviet atom bomb. All that remained was to go to the test area.

On one of the designated days in 1948 I. Kurchatov, Yu. Khariton, and P. Zernov reported at the Kremlin that the atom bomb was ready for testing. The charge (a nickel-plated plutonium sphere) for the first and as yet only bomb was demonstrated to Stalin. Stalin's wish that a second charge be made as quickly as possible was heard. Permission for the tests was received. The only thing left to do was prepare the test area.

It was the beginning of November 1948, and the country was preparing for a holiday. I carefully considered the questions that needed verification or further thought. I felt satisfied with what I had done. It seems that everything necessary had been provided for. The only thing that lay ahead was the blast in the test area tower. We were ready for the drop from the aircraft.

The question arose as to why an aerial bomb had been produced rather than a device for a physical test in the test tower, which would have been more natural. However, the country's highest leadership wanted very much to obtain a true military weapon in the shortest time possible. The Soviet Union did not have the time for any protracted opposition with the United States. There was also the issue of saving both time and equipment.

Another question raised was why the tests were being conducted in the tower rather than by dropping a prepared bomb? Was this really economically feasible. The bomb was ready for discharge and detonation from an aircraft, but it was not dropped. Its characteristics could be anticipated. The precision of the measurements, both atmospheric and instrument, as well as the possibility of navigational errors, made it necessary to conduct the tests in the tower. After the explosion on 29 August 1949 Berea, who worried all the time, asked "Is everything the same as with the American bomb? Is the effect the same?"

In the afternoon, not long before the holiday, my [Turbiner's] telephone rang. "Zvernov speaking. Viktor Aleksandrovich, I ask you to drop in on me." A pair of men were sitting in the director's office. A short stout man was sitting alongside a man who was almost twice as tall and who had a grave look. "Please come in and get acquainted. Here are your two superiors. One is your superior in matters of design, Nikolay Leonidovich Dukhov. The other is your superior in the area of testing, Vladimir Ivanovich Alferov. Please," said Pavel Mikhaylovich gesturing toward the sitting men with his hand. I walked up to Dukhov. He was the first to shake my hand. Alferov answered me with a firm handshake. I understood that the matter of direction of the design work was changing course. Something had happened despite the agreement with I. Kurchatov and Yu. Khariton.

Nikolay Leonidovich immediately proposed, "Do you want to be my deputy?" I almost reacted quickly: "No because my associates have already done everything under my supervision. All the problems in creating the first atom bomb, both the problems related to the charge and to the product overall, have already been solved. No further development is required. There were no comments from Yu. Khariton, the scientific director, regarding the basic product. As far as I know, there are no questions for those who have done the work or who have carried it out either. That is why I cannot agree to your proposal."

Dukhov grew sad. Things stayed quiet for some time. The ticking of the large clock in the corner was barely audible. There was nothing to say. Zernov sighed noisily. I turned and left after saying good-bye.

About half a year afterward, Dukhov and Alferov became acquainted with the state of affairs and began working.

After my [Turbiner] appointment as deputy scientific director and chief designer in 1948, N. Dukhov tried to change something in the design of the first bomb to his liking. Specifically, he wanted to change the shape of the so-called "piston." He wanted to switch from a round "piston" body to the shape of an element of the focusing system, but he understood that it was late to change something because the product had already been developed and was almost ready for testing. Essentially, we were waiting for the test area to be readied and for the final accumulation of plutonium.

But in the event of a negative result, Dukhov himself would be accountable.

Those who worked with Dukhov during the war years (the associates of Zh. Kotin) recall that Nikolay Leonidovich's new KV tank did not turn out well initially and that the tank crew members at the front reported to Stalin that the new tanks would burn easily in battle. He signed the memorable resolution without paying particular attention to the matter, saying "Find the scoundrel and shoot him". That time N. Dukhov was somehow saved. He was not going to risk his new career. The experience he had acquired came in handy.

Of course [Turbiner continues], it was not easy to accept at first. But there was nothing to be done. It was a case of noblesse oblige. Overall, I liked N. Dukhov. He was a lively person who enjoyed a joke. You could sense organizational and technical experience in him. But I could not suppress my feelings of resentment. To me, the turn of events seemed entirely unfair. In the end, Dukhov never really "cut his way into the ranks" as they say, and several years after the detonation of the first product he transferred to the post of director of the Aviation Automation Equipment Scientific Research Institute in Moscow.

Alferov came to the new project from the shipbuilding industry, where he had directed one of the Caspian torpedo plants for many years. He considered himself the father of high-altitude torpedo bombing. Alferov's associates had ambiguous feelings toward him. From an engineering standpoint, he was not very well trained. He always organized jobs with a great deal of noise. He evidently considered himself a great administrator.

Photo Captions [photos not reproduced]

1. p. 36: Three-time Hero of Socialist Labor and academicians I. Kurchatov and Yu. Khariton.

2. p. 37 (bottom left): At the facility.

3. p. 37 (top right): Academician I. Kurchatov at the test area (1954).

Biography of the Atom Bomb

927F0187D Moscow ROSSIYSKAYA GAZETA in Russian 24 Apr 92 p 8

[Text] Arzamas-16 (ITAR-TASS)—The entire world of nuclear physics has convened here: Russian Academy of Sciences academicians Yuliy Khariton, Yevgeniy Negin, Yuriy Trutnev, and Aleksandr Pavlovskiy; corresponding members of the Russian Academy of Sciences Boris Litvinov and Lev Feoktistov; and other doctors of sciences, designers, investigators, and workers. A conference is being held on the history of the development of the first prototype nuclear weapons.

"The work began with two laboratories: one theoretical and the other an experimental design and testing laboratory. They resided in the same building. They assumed that their stay would be brief, so they did their jobs quickly and precisely," recalls Vladimir Vzorov. "They wanted to accomplish everything in a short period and then leave. They worked incessantly 12 to 14 hours at a time without adequate experience in safety engineering. Chief designer Yuliy Borisovich Khariton organized the work so that the government job would be completed very quickly. It was called a brainstorm. A group of idea generators was created: Yakov Zeldovich, Veniamin Tsukerman, Kirill Shchelkin, Nikolay Dukhin, Samvel Kocheryan, and a group of designer-investigators."

The conference participants expressed their anxiety over the current state of affairs. Russian Academy of Sciences corresponding member Lev Feoktistov, for example, turned his attention to two forces facing our nuclear scientists. The first is the Chernobyl tragedy. In the scholar's opinion, everything happened because the nuclear power plant had been placed in hands that were not entirely competent and because persons who were not specialists in nuclear physics had begun working there. To avoid another Chernobyl, nuclear physicists should again take all nuclear power plants and the operation of all reactors back under their own control. The second force toward which the scientist turned his attention was that of the beginning of the disarmament process and the huge amount of plutonium that will be returned from charges. A worthy use must be found for it.

The Disappearance of Lipovka: Underground Nuclear Tests Conducted in Baskortostan

927F0187E Moscow SOVETSKAYA ROSSIYA in Russian 28 Apr 92 p 8

[Article by SOVETSKAYA ROSSIYA correspondent M. Merzabekov]

[Text] It is no longer a secret that beginning in the 1960's, a series of underground nuclear explosions were conducted in Baskortostan. A. Shishkov, an eyewitness of the events who is also the former chairman of the Pobeda kolkhoz in the Meleuzov Rayon and is currently the chairman of one of the permanent commissions of the Supreme Soviet of the republic of Baskortostan, for example, states the following:

"There is no justification for those experiments, regardless of any good intentions with which they may have been conducted. Indeed the explosions were conducted in a densely populated region—close to the cities of Meleus, Kumeratau, Salavat, and Ishimbay. The villages of Darino, Nikolayevka, Lipovka, Kazankovka, Karagan, Kutushevo, Terekla, Vasilevka, and Samarovka are located within a radius of 1 to 10 km from the explosion site....

"The local inhabitants were not informed of anything. A commission of some 'numbered' institute simply appeared at the kolkhoz one beautiful day and began inventorying the cattle, buildings, etc.

"The last explosion was conducted no later than in 1980. From the outside, the experiment was set up as 'civil defense training.' During the experiment, the inhabitants of the village of Lipovka, which was located near the explosion's epicenter, were resettled in another village. The populations of the remaining villages were not evacuated. The inhabitants were told to leave their homes and sit or lie on the ground. The sick were carried out. You can imagine the commotion that was created!

"To keep the population from 'interfering' during the subsequent explosions, all inhabitants of Lipovka were permanently resettled in neighboring villages and cities. The experiment was interrupted despite its organizers' wishes. It seems that nature herself decided to delay it. A gas blowout occurred while the boreholes were being drilled for the explosion set for 1982. Several dozen fire trucks took 2 to 3 days to extinguish the raging fires.

"And so the 'Bashkir series' of nuclear explosions came to an end. A single cemetery is all that now remains of the now-nonexistent village to remind people of that inhuman act.

"The effect of the explosions on people's health has still not been studied thoroughly. The fact that local springs have dried up or that new ones have suddenly gushed up evidently indicates a shifting of the underground strata. The sharp increase in mortality in the 'test' territory is also alarming. Several members of the brigades servicing the drilling rigs died at a young age. The true cause of death is now difficult to establish based on diagnoses. However, the local population has begun suffering from cancer and from diseases of the liver, kidneys, thyroid gland, and gastrointestinal tract."

How do specialists assess the experiment's results? I. Pastukhov, chief engineer of the Ishimbayneft oil and gas recovery administration, says the following:

"The idea of the experiment was born at the Moscow Institute imeni Gubkin. The idea was to increase the oil yield of oil works by forming cracks in seams and by using the effects of temperature. No similar experiments were conducted. Was the game worth a candle from an economic standpoint? We industrial workers who have stood by the oil tanks for all these years have not noticed any additional increase in yields following the nuclear

shake-up of the seams. One might even suggest that instead of the anticipated effect, the pores of the oil-bearing seams were actually plugged up."

V.L. Yakhimovich, doctor of geological and mineralogic sciences, who is both a professor and renowned academician, says the following:

"In the beginning of the 1960's I was able to convince the leadership of Bashkiria to refuse to grant permission for the underground nuclear explosions that were being prepared near Ufa. Later, however, I found out that the explosions were conducted anyway in the Meleuzov Rayon. Such games with the atom 'for peaceful purposes' are far from being a harmless joke. As far as is known, radioactive water was ejected to the surface after the explosions near Sterlitamak. I remember how peasants who contracted radiation sickness after drinking water from a well lay alongside me in the hospital. At the time, our medical community totally declined to establish a diagnosis associated with radiation. In my view, statements to the effect that the radiation background at the explosion site were calm and that no one suffered must not be taken as the truth. Indeed, the consequences will only be seen years from now."

Judging by the inhuman tests of the past, society must above all else remember to help the victims. The explosion zone demands painstaking monitoring and testing, and those citizens who have suffered demand protection and health care.

Assessment of Effect of Clay Soil Leaching on Deformability of Crimean Nuclear Power Plant Foundation

927F0183A Moscow INZHENERNAYA GEOLOGIYA in Russian No 1, Jan-Feb 92 pp 23-39

[Article by R.S. Ziangirov, O.V. Aslibekyan, Ye.N. Samarin, V.N. Kutergin, B. Rakhmanov, Production and Scientific Research Institute of Civil Engineering Surveying; UDC 624.131]

[Abstract] The danger of nonuniform foundation settling on saline soils due to the leaching of the water-soluble salt complex as a result of process and drinking water leakage and the soil salinity criteria and parameters used to determine the salinization characteristics are discussed. Various aspects of the process of chemical suffosion of saline clay soils which lie under the foundation of the Crimean Nuclear Plant (AES) are considered and the effect of leaching on the behavior of the soil deformability is estimated. The microstructure of clay soils under the site is examined microscopically and the behavior of physical and physicomechanical characteristics of clay soils as a result of leaching at various depths, e.g., looseness, moisture content, plastic limit and number, density, porosity, gypsum concentration, and strain moduli, are summarized. The hydrogeological conditions at the KAES site are assessed and compression curves of the loam and the behavior of total strain moduli as a function of leaching are plotted. The suffosion settling of the foundation is charted. Studies involving lab experiments and numerical simulation indicate that under present conditions, leaching cannot lead to a substantial change in the structure foundation deformability since the degree of soil leaching in the aeration zone during the forecast period does not exceed 0.07 while that of water absorbing soil does not exceed 0.02; as a result, the straining modulus decreases by no more than 16%. Figures 10; tables 5; references 9.

Utilizing Country's Underground Space for Nuclear Power Industry Purposes

927F0179A Moscow PODZEMNOYE I SHAKHTNOYE STROITELSTVO in Russian No 1, Jan 92 pp 12-17

[Article by N.N. Melnikov, V.P. Konukhin, V.A. Naumov; UDC 621.311:621.039(24)]

[Abstract] The shortcomings of the country's nuclear power industry made public in the wake of the Chernobyl accident prompted interest in the concept of locating nuclear power plants underground so as to reduce the consequences of a possible nuclear accident. The experience of existing underground nuclear power plants in the United States, Norway, Sweden, France, and Switzerland is summarized and a complex of exploratory research work in this field carried out at the Mining Institute of the Kola Scientific Scented of Russia's Academy of Sciences in 1987-1991 is outlined. The issues of underground nuclear power plant safety under the effect of sabotage actions or natural phenomena, the nuclear power plant safety during the operation and in the case of likely or hypothetical accidents, underground nuclear power plant decommissioning and radioactive waste burial, nuclear power plant siting, and engineering and economic feasibility of underground nuclear power plant siting are addressed. It is noted that underground nuclear power plant and radwaste (RAO) burial siting is a promising trend in improving the nuclear power industry. Although most of the aspects of the problem call for further detailed theoretical and experimental research, implementation of underground nuclear power plant and radwaste burial projects is practically feasible at today's engineering and technology level. References 2.

Study of Recent Earth Crust Movements in Sites for Nuclear Power Plants

927F0102A Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 10, Oct 91 pp 19-21

[Article by A.A. Lopanchuk; UDC 551.24:528.48]

[Abstract] Site selection for nuclear power plants requires preliminary geodetic study of earth crust movements so as to ascertain stability of the earth surface within those sites. Such a study must include geodynamics of the entire region and reveal tectonic movements throughout it, must reveal activity of nearby faults both horizontal and vertical so as to indicate the degree of stability of individual rock layers, must indicate the degree of stability of second-order faults as well as of the principal ones, and must reveal microcracks and faults

throughout the region where a nuclear plant exists. The study must yield sufficient information for mapping seismic activity and tectonic movements, especially within the earth crust block underneath the proposed construction site. Following such a study and on the basis of the available data, geomonitoring and automatic geodetic scanning of the proposed site are necessary for protecting the environment during construction of a nuclear power plant and possible attendant reactivation of latent geodynamic processes.

A Qualitative Analysis of the Effect of Steam-Steam Reheating on the Operating Efficiency of Wet Steam Turbine Systems

927F0190A Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: ENERGETIKA in Russian No 2, Feb 92 (manuscript received 22 Oct 91) pp 56-61

[Article by V.M. Borovkov, doctor of technical sciences and professor, and N.N. Davidenko, V.K. Myasnikov, N.I. Zhuk, and N.E. Molodkina, engineers, Leningrad State Technical University and Kalinin Nuclear Power Plant; UDC 621.165;621.039.5]

[Abstract] The operation of nuclear power plants with slow reactors in the long-range future will inevitably involve using a saturated steam-steam turbine cycle. At the nuclear power plants with VVER and RBMK reactors that are currently in operation in the USSR, the initial pressure of the active medium will barely exceed 7.5-8 MPa in the near future. From the standpoint of the thermodynamic cycle, the optimum initial pressure is somewhere between 12 and 15 MPa. At pressures of 7.5 to 8 MPa, efficiency is reduced by more than 1-1.5% versus the efficiency that can be obtained at higher pressures. In view of this fact, the authors of the study reported herein performed a qualitative analysis of the effect of steam-steam reheating on the operating efficiency of wet steam turbine system. They focused their analysis on the limiting regenerative cycle of a wet steam turbine system at a nuclear power plant first without separation and reheating and then with various separation and reheating circuits (two-stage external separation without reheating and single-stage separation and two-stage reheating using the steam from the flow area and live steam). The analysis performed led the authors to conclude that adding any type of steam-steam reheating to the limiting regenerative cycle examined will reduce the cycle's thermal efficiency both in its rated mode and under partial loads. They also concluded that using live steam for superheating has the greatest negative effect. The efficiency of a regenerative cycle without separation but with one- or two-stage separation was found to approach the efficiency of a Carnot cycle for selected initial and end steam temperatures (pressures). Finally, the authors concluded that a comparative evaluation of actual circuits of nuclear power plants with and without steam-steam superheating must be preceded by detailed computer calculations performed for the rated and partial load modes being compared. Figures 3; references 7 (Russian).

On Results of One Experiment to Measure Speed of Sound in Foam

927F0228A Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 5-11

[Article by F.I. Vafina, I.I. Goldfarb, I.R. Shreyber, Institute of Northern Development Problems at the Siberian Department of Russia's Academy of Sciences; UDC 532.529+534.19+541.182.45]

[Abstract] Gas-and-liquid foams—a particular case of a two-phase medium with a close-to-unity gas content and peculiar microstructure—and their acoustic characteristics are discussed and an attempt is made to explain the dependence of the speed of sound in foam measured by Moxon, Torrance, *et al* on the moisture content. To this end, a model of sound propagation in foam is developed allowing for the fact that the foam dispersivity is equal to 0.75 and the harmonic vibrations frequency, on whose basis the speed of sound is determined, is equal to 3.14×10^4 s^{-1}. The precise heat exchange between the phases is ignored and it is assumed that the change in the gas volume in the bubbles is adiabatic while the liquid is incompressible. The analysis is limited therefore to the characteristics of linear acoustic disturbance propagation. The model is a logical extension of the theory proposed by Goldfarb, Shreyber, *et al.* The model takes into account the liquid movement in the system of Plateau-Gibbs channels. It is noted that the liquid motion affects the foam's dispersion properties only in the high frequency area. Figures 2; references 13: 10 Russian, 3 Western.

Sound Wave Generation in Liquid by Noncoherent Optical Radiation

927F0228B Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 34-40

[Article by A.P. Guryev, P.N. Rogovtsev, Scientific Research Institute of Comprehensive Testing at the All-Union Scientific Center of the State Optics Institute imeni S.V. Vavilov; UDC 534.7:535.34]

[Abstract] The optoacoustic effect—sound generation under the effect of optical radiation—and attendant phenomena, such as evaporation and optical breakdown accompanied by an intense thermal and hydrodynamic disturbance, are discussed and sound wave generation during the interaction of optical radiation of noncoherent sources, e.g., pulse Xe lamps, with liquids which absorb within a $\geq$200 nm wavelength range is investigated experimentally. The evaporative sound wave generation mode is studied in detail and its difference from laser-stimulated sound generation is addressed and the broad optical radiation band is noted. The role of local optical inhomogeneities on the quartz bulb interface with the liquid and of the impurities is examined. It is shown that the origin of microinhomogeneities has little effect on the phenomenon. Oscillograms of the light and acoustic pulses in the cylindrical test tray with water at various distances from the lamp, the behavior of the maximum bubble diameter and number on the quartz wall during consecutive flashes, and the dependence of the pressure pulse amplitude on the number of lamp flashes during successive evaporation of an oil film on the bulb are plotted. An optoacoustic lamp generator is designed and a contact method of exciting sound is developed on the basis of the evaporative sound wave generation analysis. The generator is tested in the Black Sea. The authors are grateful to N.G. Semenova for useful advice. Figures 4; references 10.

Power Spectrum of Ring Pressure Fluctuation Modes on Surface of Cylinder in Axial Flow

927F0228C Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 46-52

[Article by V.I. Zarkhin, D.G. Robikov, V.M. Tkachenko, Central Scientific Research Institute imeni A.N. Krylov; UDC534.222]

[Abstract] The characteristics of the turbulent boundary layer forming on the outer surface of an extended cylinder in axial flow which distinguish it from the boundary layer on a plate are addressed and the power spectrum of the ring modes of turbulent pressure fluctuations is investigated and compared to the conventional power spectrum produced under the same conditions. The effect of the angle of attack on the ring mode power spectrum is examined and the structure of the turbulent flow along a long cylinder and its utility for solving such application problems as marine seismic prospecting of mineral deposits are discussed. The turbulent pressure fluctuations characteristics are measured in a low-noise low-turbulence test bench specifically designed for measuring the pseudosonic turbulent pressures in the boundary layer. A schematic diagram of the testing unit is cited and power spectra recorded by different detectors are plotted. The development of coherent axisymmetric structures due to the ring eddy formations on the outer part of the boundary layer which move downstream at a rate of 0.83 of the flow velocity is noted. The energy contribution of these eddies depends on the frequency and reaches 10%. Deviations from the axial flow result in a partial ring structure breakdown and increase the energy of small-scale components. These effects are manifested within a -8° to +8° incidence angle range due to the approach flow separation leading to an increase in the spectral density of turbulent pressures at low frequencies. The authors are grateful to N.V. Vitvinsky for making pressure pickups and I.I. Lositskiy for helping with the experiment. Figures 5; references 9: 1 Russian, 8 Western.

Longitudinal Wave Excitation in Immersed Rod by Radiation Sound Source in Liquid

927F0228D Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 59-64

[Article by V.V. Zosimov, Acoustic Institute imeni N.N. Andreyev at Russia's Academy of Sciences; UDC 535.3]

[Abstract] The use of acoustic phenomena of the penetrating radiation interaction with matter for recording high energy articles in a liquid and measuring weak concentrations of radiation-absorbing impurities in a liquid and the possibility of fiber optic acoustic field tomography are discussed and synchronous excitation of longitudinal waves in a thin immersed rod by a radiative acoustic pulse source in a liquid is investigated. Attention is focused on the conditions under which the contributions of various sources to the longitudinal wave excitation in the rod are cophased as a result of which the excited wave is amplified. The analysis is limited to the contribution of pressure ignoring viscous forces. A nonuniform wave equation is solved for the acoustic pressure in the liquid. The effect of the radiation pulse is considered as a source of instantaneous heat release during the narrow penetrating radiation beam propagation. It is shown that synchronous excitation peaks when the longitudinal wave velocity in the rod is equal to that of the wake incident from the liquid since the cylinder—or fiber—serves as a guide for elastic waves. Figures 1; references 7: 6 Russian, 1 Western.

Phase Synthesis of Acoustic Antenna Arrays With Interacting Elements

927F0228E Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 65-69

[Article by N.M. Ivanov, Self-Supporting Scientific Production Association of the Special Pyezopribor Product Design Office at the Rostov University; UDC 681.883.677]

[Abstract] The shortcomings of existing solutions of the problem of acoustic and electromagnetic radiating antenna array synthesis based on a specified complex or amplitude directivity pattern (KhN) and the stringency of the amplitude-phase distribution of the exciting voltages are addressed and a more flexible method of phase synthesis of acoustic antenna arrays with interacting elements on the basis of a given amplitude directivity pattern (AKhN) is considered. In addition to approximating the shape of a given amplitude directivity pattern, the method makes it possible substantially to improve the antenna operating condition and facilitate practical antenna design. The original relationship for the complex antenna directivity pattern is derived. The problem is considered as a two-criteria problem of minimizing the standard deviation of the specified and actual directivity patterns for the maximum acoustic antenna power which is solved by a single-parameter efficiency function. In solving the efficiency function minimization problem, first-order mathematical programming methods are used. It is illustrated by solving the problem of synthesizing an equally spaced planar array with 40 piston radiators in an infinite acoustic rigid screen. The proposed approach may be used for selecting the phase distribution which makes it possible to form an amplitude directivity pattern of a given shape and increase the antenna efficiency. The author is grateful to M.D. Smaryshev and Yu.Yu. Dobrovolskiy for constructive remarks. Figures 2; references 10.

Acoustic Wave Propagation in Elastic Layered Media

927F0228F Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 70-78

[Article by V.K. Ignatovich; UDC 534.231.1]

[Abstract] The primal and linear problems of wave propagation in layered media are outlined and the difficulty of sewing the solutions on the interface in the case of acoustic waves is addressed. A method in which the following technique is utilized is discussed: imaginary infinitely narrow slots filled with a certain imaginary standard medium are inserted between the layers; in the case of acoustic waves, this may be a medium with a unitary density and unitary longitudinal and transverse wave velocities. Then the amplitude matrices of a single layer's reflection and transmission are calculated not by sewing the boundary value conditions but with the help of recursive relations in which the separated layers' amplitude matrices figure prominently. The proposed method is suitable not only for considering unidimensional problems but also for such problems as diffraction on scatterers orderly positioned in a three-dimensional space, e.g., neutron diffraction on a three-dimensional crystal. It is shown that an identical acoustic problem may be formulated. It is speculated that the use of the proposed procedure makes it possible greatly to simplify the processing of acoustic measurements and improve the relevant instruments. The author is grateful to O.A. Godin for interest in the study. References 10: 7 Russian, 3 Western.

Nonlinear Sound Beam Propagation in Conducting Liquid With Gas Bubbles

927F0228G Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 87-92

[Article by S.V. Korsunskiy, Hydromechanics Institute at the Ukrainian Academy of Sciences; UDC 534.222:533.951]

[Abstract] The use of nonlinear wave processes in gas-and-liquid conducting media under the effect of magnetic fields in making contactless diagnostic and dynamic process control devices for two-phase hydrodynamic systems and propagation of finite-amplitude disturbances in the gas- or vapor-and-liquid media are considered and propagation of bounded sound beams of

finite amplitude in an electrically conducting incompressible liquid with gas bubbles under the effect of a static magnetic field is investigated on the basis of the magnetic hydrodynamics equation of a homogeneous isotropic gas-and-liquid medium. To this end, the Khokhlov-Zabolotskaya-Kuznetsov (KhZK) equation complemented with terms describing the magnetohydrodynamic (MGD) interaction and wave dispersion is derived by the slowly varying profile method and the effect of the liquid phase's gas content and electric conductivity on the acoustic disturbance evolution is examined. The effect of dispersion and dissipation on the parameters and structure of weak shock waves is analyzed in the framework of the KhZK model. The second harmonic amplitude behavior on the beam axis is plotted. The conclusion is drawn that the balance of nonlinear, dissipative, and dispersion phenomena in such a medium determines the formation of elongated "kink" solitons and the presence of weak shock waves with a monotonic or oscillating structure. Figures 1; references 12: 9 Russian, 3 Western.

Explicit Finite Difference Method of Calculating Acoustic Field in Medium With Variable Density and Attenuation

927F0228H Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 93-99

[Article by Yu.S. Kryukov, Atoll Scientific Research Institute; UDC 534.231.1]

[Abstract] Earlier studies (*Akusticheskiy zhurnal* Vol 32 No 2, 1986 and Vol 34 No 6, 1988) of the use of explicit finite difference methods for computing the acoustic fields in waveguides with variable parameters along the path are continued and an acoustic model of an irregular waveguide with a given depth and variable density and volume absorption factor of the medium is considered. The sonic field excited by a harmonic source is described in a two-dimensional case by a wave equation. A computation algorithm is developed on the basis of solving a modified wide-angle parabolic wave equation (ShPU) derived by approximating the square root $(1+x)$ operator in the form of a quadratic polynomial. The solution does not call for rigid constraints on the difference net interval in the vertical coordinate. The acoustic field analysis algorithm is realized in the Fortran-77 language in a UNIX operating system (OS) on computer and test problems are used to check the computation accuracy. The proposed procedure makes it possible to analyze acoustic fields in waveguides with layer-by-layer variable parameters with a specified accuracy and is suitable for practical applications. The high computation speed of the method is noted. Figures 5; references 7: 4 Russian, 3 Western.

Nonlinear Sound Scattering by Pulsating Sphere

927F0228I Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 100-107

[Article by L.M. Lyamshev, P.V. Sakov, Acoustic Institute imeni N.N. Andreyev at Russia's Academy of Sciences; UDC 534.222.2]

[Abstract] The problem of nonlinear sound scattering by bodies whose boundary performs small vibrations is divided into two parts in the framework of Westervelt's quasilinear approximation: one related to the bulk interaction of the external source field, i.e., the incident and diffracting waves and the oscillating surface emission field, and one to the interaction of the external source field with the oscillating boundary. In analyzing nonlinear scattering of sound, the boundary effects are ignored and attention is focused on the bulk effect. For certainty's sake, an acoustically rigid sphere pulsating at a small amplitude relative to the nondisturbed position is considered whereby a planar wave is incident upon the sphere and after scattering, generates the second component of the primary sound field. The secondary sound field component p_+ at the sum frequency is examined and denoted as a volume integral. The principal terms of the high-frequency secondary sound field asymptotics under nonlinear scattering are derived. It is noted that a transition from the sum frequency to a field description for the difference frequency is a mere formality in most cases. Nonlinear sound scattering applications for examining the nonlinear effects during the sound scattering by radiators or investigating phase conjugation in acoustics are discussed. Figures 2; references 8: 3 Russian, 5 Western.

Acoustic to Electric Pulse Transformation by Cylindrical Piezoelectric Ceramic Shell

927F0228J Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 144-149

[Article by V.G. Savin, Kiev Scientific Research Institute of Hydraulic Instruments; UDC 539.6.013.42]

[Abstract] Incidence of a nonstationary planar pressure field upon an infinitely long circular piezoelectric ceramic cylindrical shell which is surrounded on the outside and filled on the inside with ideal compressible liquids whereby the wave front is parallel to the cylinder axis and the shell and polarized in the radial direction by the electrodes applied to its outer and inner surfaces is considered. One of the electrodes may be separated by vertical cuts. The electric signal resulting from the shell straining is picked up from each section individually. The cylindrical transducer movement is described in the framework of the applied theory of thin piezoelectric ceramic shells under the constraint that the normal component of the electric induction vector is equal to

zero (i.e., the no-load condition). The proposed procedure is based on utilizing integral Laplace transform in time whereby the unknown quantities are determined from Voltera's integral equations solved numerically. A computer routine is developed for analyzing the transient conditions in a hollow ceramic piezoelectric shell from the TsTBS-3 material. Figures 2; references 6.

Two-Phonon Self-Induced Transparency in Anisotropic Paramagnetics

927F0228K Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 170-171

[Article by G.T. Adamashvili, R.R. Khomeriki, Tbilisi State University imeni Iv. Dzhavakhishvili; UDC 539.12]

[Abstract] The phenomenon of self-induced acoustic transparency (SIP) first described by Shiren in 1970 for cubic lattice crystals is discussed and extended to the case of two-phonon transitions induced by the acoustic wave which alters the physical picture of self-induced acoustic transparency and therefore calls for a special analysis. The issue of two-phonon self-induced transparency in uniaxial crystals is addressed and a hexagonal lattice crystal containing paramagnetic ions in a low concentration with an electric spin of ½ is considered. The crystal is placed in a static magnetic field with the z-axis directed along the crystal's acoustic axis. The transverse polarized extraordinary acoustic wave is examined. It is shown that the particular case of two-phonon self-induced acoustic transparency can be extended to the case of discrete saturation. It is also noted that such effects in anisotropic media may be induced by an extraordinary acoustic wave with a longitudinal polarization. An analysis of the findings indicates that in the case where the spin of impurity atoms is equal to unity, the maximum pulse delay in two-phonon self-induced acoustic transparency is observed at a zero angle between the z-axis and the wave vector and in paramagnetics with a ½ spin, the maximum delay is expected in the vicinity of 45°. References 8: 6 Russian, 2 Western.

Stimulated High-Frequency Wave Packet Scattering in Gas-Liquid Medium

927F0228L Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 38 No 1, Jan-Feb 92 pp 174-176

[Article by V.G. Kovalev, V.B. Fridlender, Pulsed Processes and Technologies Institute at the Ukrainian Academy of Sciences; UDC 532.529]

[Abstract] The mechanisms of resonant nonlinear sound scattering by a free surface in the presence of gas bubbles in general and scattering in the ocean where both low- and high-frequency noise is always present due to a large number of gas bubbles leading to sound attenuation and first-order decay instability due to the buildup of noise waves scattered at considerable angles in particular are discussed. This type of high-frequency sound instability on the order of the gas bubble resonance frequency at a low-frequency sound noise is investigated; in so doing, the hydrodynamic nonlinearity is ignored and a system of equations describing sonic waves in the gas-and-liquid medium is derived. The study shows that the times of sound scattering by the bubbles and by the liquid surface may be commensurate, making it necessary to take into account both processes in studying stimulated Raman sound scattering on the ocean surface and the low-frequency sound generation under the surface disturbance excitation by ultrasonic beams. References 9.

Pressure Pulse Transfer to Free-Running Neodymium-Laser-Irradiated Metal and Insulator Targets

927F0227A Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 20-23

[Article by L.I. Kuznetsov, Novosibirsk; UDC 535.9.082:53.082.73]

[Abstract] Pressure oscillations on metal and dielectric targets are investigated. To this end, an experiment is conducted in a vacuum pulse chamber (VIKA) whereby pulsed laser radiation (LI) at a 1.06 μm wavelength and a half-power duration of 3×10^{-4} s is focused on metal and insulator targets in the chamber whose pressure is manipulated within 10^5 to 10^{-2} Pa. The irradiation spot is equal to 6 mm in diameter in most cases while the target diameter is 20 mm. The targets are installed on a piezoelectric transducer characterized by the presence of a long acoustic guide behind the piezoelectric pressure-sensitive element which makes it possible to space the main and reflected signals in time by up to 1.5 ms. Pressure oscillations on the rear side of a lead target are detected at a flux density of about 2 MJ/cm^2. As the flux density increases, the relative values of pressure oscillations drop against the background of total pressure in the exposure spot and oscillations become unnoticeable. As the normalized flux density increases from 70 to 800 J/cm^2, the pressure rises by approximately fifteenfold. The mechanism of such behavior is discussed and the pressure oscillations are attributed to self-excited oscillations of the target self-shielding or an absorption spike of the light-induced erosion flame in plasma under unstable evaporation conditions. The conclusion is drawn that these phenomena are most likely due to the effect of gas dynamic processes in the near-flame space on the development of pressure oscillations on the target. Figures 5; references 4.

Underground Explosion Shock Wave Front

927F0227B Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 23-30

[Article by N.I. Shishkin, Chelyabinsk; UDC 624.1525]

[Abstract] Various approaches to determining the law of motion of an underground detonation shock wave and simulating the initial stages of such an explosion, e.g., as a scattering shell, are discussed. Both the warm and cold pressure components in the matter behind the shock wave (UV) front are taken into account. The medium in which the explosion occurs is assumed to be a solid porous body (soil) and the explosion is simulated by adiabatic expansion of plasma from the explosion products which is treated as a perfect gas with an adiabatic exponent of γ_3. The initial explosion product density is equal to the ambient soil density. The pressure developing in the soil and the resulting spherically symmetric motion are expressed by gas dynamics equations. The soil's equation of state and boundary conditions on the contact boundary are derived in the form of pressure continuity and normal velocity component. The solution of the equations indicates that in the underground explosion, the cold pressure and internal energy component is substantial and cannot be ignored in favor of the warm component. The findings confirm that the description of the scattering shell is accurate even in the area where the wave cannot be regarded as strong. The simplicity of this approximation makes this method convenient and suitable for analyzing the underground detonation shock wave front parameters and describing explosions not only in the soil but also in metal and other condensed media. Figures 6; tables 1; references 11: 6 Russian, 5 Western.

Analysis of Spatial Flow Past Spherically Blunted Cones in Symmetry Plane Neighborhood Under Various Flow Conditions in Shock Layer and Gas Injection From Surface

927F0227C Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 72-78

[Article by A.V. Bureyev, V.I. Zinchenko, Tomsk; UDC 533.6.011.536.24]

[Abstract] The flow past a spherically blunted cone is investigated in the framework of the model of total viscous shock layer in the neighborhood of the symmetry plane within a broad range of Reynolds numbers in the case where different flow conditions are realized in the shock layer. A set of equations is derived for the viscous layer in the vicinity of the flow symmetry plane in a natural system of coordinates fixed in the body symmetry axis and the unknown functions and coefficients are expanded into a series in order to obtain a system of equations for averaged characteristics. The Fourier series produced by expanding the pressure is truncated and the effect of the angles of attack and of taper and their ratio on the pressure distribution is examined. The effect of the injected gas rate on the heat flux toward the body in the vicinity of the symmetry plane on the windward side in the case where gas is injected through a porous spherical blunting is considered. An analysis of the findings shows that despite the considerable difference in the heat flow distribution on the spherical part of the axisymmetric body due to the difference in the rate laws, the length of the thermal shield is determined primarily by the total mass of the injected coolant gas and depends little on the pressure distribution on the spherical blunting. The authors are grateful to V.D. Goldin for making available the results of nonviscous spatial flow analyses. Figures 5; references 14: 8 Russian, 6 Western.

Effect of Rarefaction on Nonstationary Interaction of Underexpanded Supersonic Jet With Perpendicular Obstacle

927F0227D Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 78-83

[Article by A.V. Savin, Ye.I. Sokolov, V.S. Favorskiy, I.V. Shatalov, Leningrad; UDC 533.6.011.8]

[Abstract] The breakdown mechanism of steady-state flow in front of an obstacle perpendicular to the axis of the supersonic underexpanded jet and the abrupt transition to nonstationary flow accompanied by obstacle vibrations at a frequency on the order of several kilohertz and pressure fluctuations on the obstacle at the same frequency are discussed and the effect of viscosity on the process of nonstationary interaction of the jet with an obstacle is examined in order to develop a sound theory of the process. The experiment is conducted in a vacuum chamber using U-tube manometers and thermocouple pressure gauges and vacuum meters to record the pressure. The frequency spectra and the dependence of the integral acoustic emission level and pressure fluctuations on the obstacle on the mutual position of the nozzle and the obstacle are examined and the transducer signal is processed using 22E equipment made by RFT (Germany). The effect of rarefaction on the process of nonstationary jet interaction is studied while manipulating the Reynolds number by proportionately regulating the pressure. The effect of the Re number on the flow can be examined due to the presence of clear nonstationary condition boundaries. The appearance of nonstationary conditions is attributed to the existence of a shock wave structure in the jet and its transformation with a change in the Re number. An increase in the off-design flow regime, i.e., the underexpansion, which cases a proportionate increase in both longitudinal and transverse dimensions of the shock wave structure leads to a decrease in the fluctuation frequency and virtually does not affect the Reynolds number up to an underexpansion value of 500. Figures 6; tables 2; references 9.

Experimental Investigation of Round Aluminum Plate Straining and Failure Under Impact of Shock Wave

927F0227E Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 93-97

[Article by L.Ye. Kolegov, E.E. Lin, V.T. Ryazanov, A.I. Funtikov, Arzamas; UDC 539.3]

[Abstract] The dependence of the residual sag of aluminum plates with various diameters and thicknesses on the impulse load created by setting off a flat explosive (VV) charge in a shock pipe is investigated experimentally and an attempt is made to establish the critical values of residual sag which are responsible for fracture. The study is prompted by the increasing use of plates as shock pipe diaphragms fastened peripherally by, e.g., clamping the plate between two flanges with the help of a bolt joint. The flat charge is set off simultaneously at several points evenly spaced on the surface and the impulse load is manipulated by changing the charge thickness. The pulse load is measured ballistically by projecting a sufficiently heavy nondeformable target installed in place of the plate under study whereby the shape of the shock wave reflected by the rigid wall is recorded by a piezoelectric transducer. An analysis shows that critical values of residual sag responsible for failure can be expressed by a generalized formula which is valid at all values of the diameter ratios (inside pipe and flanged joint diameters), i.e., is valid for any type of failure. The findings can be used for selecting shock pipe diaphragms. Figures 6; references 7: 6 Russian, 1 Western.

On Disturbance Development in Supersonic Boundary Layer

927F0227F Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 98-101

[Article by S.A. Gaponov, Novosibirsk; UDC 532.526]

[Abstract] The development of turbulence in supersonic flows and its effect on the stability of compressible boundary layers are investigated on a flat plate both in a parallel flow approximation and allowing for the lack of parallelism using simplified Dan-Lin and Gaponov's equations, respectively. The behavior of the mass rate fluctuation enhancement degree on the slope of the wave vector to the principal flow direction and the dependence of the wave number and phase velocity in the *x*-direction on the wave number in the *z*-direction are plotted. An attempt is made to explain the upstream disturbance penetration observed experimentally at the Theoretical and Applied Mechanics Institute. To this end, additional oscillation modes are considered and the dependence of the real and imaginary parts of the wave number on the frequency parameter is examined. It is noted that the nondimensional degree of the upstream disturbance attenuation depends little on the frequency parameter; additional analyses show that a Reynolds number decrease from 670 to 200 leads to an increase in the imaginary wave number part by a mere 25% while the dimensional value increases substantially since the boundary layer thickness decreases by a factor of 2.5. The conclusion is drawn that stationary waves corresponding to two modes may be present in the boundary layer. Figures 4; references 11: 8 Russian, 3 Western.

Pulsation Mechanism of Supersonic Separated Flow in Front of Spike-Tipped Cylinder

927F0227G Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 101-107

[Article by V.I. Zapryagayev, S.G. Mironov, Novosibirsk; UDC 534.13:533.6.011.5]

[Abstract] The difficulties of using spike-tipped nose cones in front of blunt bodies for reducing drag due to the unfavorable effect of intensive flow pulsations which depends on the nose shape, the spike length, and the flow's Mach number and are due to the excitation of self-sustained vibrations in the front separation zone in front of the spiked end are discussed and an attempt is made to describe the mechanism of pulsations on a spike-tipped cylinder and compare it to experimental data on the pulsation character when the spike length is commensurate with the distance to the separated shock wave. The experiment is carried out in a model of a cylinder with a 100 mm diameter with an axial spike with a 4 or 16 mm diameter and a conical tip. The spike length changes discretely within a 0-1.5 range. The test is conducted in a supersonic wind tunnel at a zero angle of attack in a cold air at 280K at the flow Mach numbers of 2.0 and 3.0. Schlieren photographs corresponding to various flow conditions and pressure fluctuation oscillograms are presented. Self-excited vibrations are examined starting with the time moment at which a minimum pressure is recorded on the cylinder end which corresponds to the maximum bow shock separation from the end. The presence of a local separation area on the lateral surface is demonstrated experimentally. The tangential discontinuity bending emerging from the triple point in the schlieren photos is attributed to pressure gradients. An analysis of these photographs referenced to the pressure fluctuation phases shows that the connection between the bow shock position and the periodic fluctuation phase is generally similar to the pattern of developed self-sustained oscillations. The onset of nonperiodic fluctuations is attributed to the fact that a slight extension of the spike tip beyond the shock wave leads to a stability loss in the vibratory system while there is no effective feedback, as in the case of jet systems. Figures 3; references 17: 15 Russian, 2 Western.

Approximate Solution of Dynamics Problem of Cylindrical Shell in Soil Whose Surface Is Exposed to Movable Load

927F0227H Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 133-137

[Article by R.G. Yakupov, Ufa; UDC 539.374]

[Abstract] The issue of the effect of a movable load on underground structures is addressed in the framework of the problem of the structure's interaction with the ambient medium and an incident wave—a very complicated problem which is usually solved numerically. It is stressed that despite the difficulty, the analytical solutions of this problem are quite important for checking the accuracy of numerical methods. It is assumed that a triangular load wave of a certain length whose shape remains unchanged with propagation is moving at a constant front velocity on the surface of a half-space filled with soft soil while a circular cylindrical hollow shell with a certain radius and wall thickness is present at a certain depth in the half-space. The problem of finding the stresses and strains developing in the shell under the effect of the loading wave under the movable load in the half-space is solved and a numerical example for sandy soil is cited. A stress diagram of the loaded shell is plotted based on calculations made on an Elektronika-D3-28; the time necessary for analyzing the stress at a given point is equal to 2 min. Figures 4; references 6.

Physical Causes and Formation Mechanisms of Boundary Zones During Two-Dimensional Shock Compaction of Powder Materials

927F0227I Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6(190), Nov-Dec 91 pp 154-161

[Article by N.A. Kostenko, Novosibirsk; UDC 532.593:621.7.044.2]

[Abstract] The development of structural inhomogeneity zones during the two-dimensional shock compaction of powder materials (PM) and its likely physical causes and formation mechanism are discussed and the inconsistency of dynamic models of the process is noted. Likely versions of flows developing under oblique reflection of shock waves (UV) in powder materials from the surface of a monolithic obstacle are investigated and the effect of the flow patterns on the structural characteristics of the resulting compacts is examined. To this end, an experiment is conducted with Ti, Ni, Cu, TiNi, and tin bronze powders; the latter have close-to-spherical particles. The powder dispersivity varies within 20-50 to 400-630 μm while the initial powder material density is equal to 63% of the monolithic state density. Al, Cu, Ni, and Mo obstacles are used in the experiment; the experimental procedure and numerical analysis methods are outlined. Two-dimensional flow regimes and boundary layer structures, boundary effects on complex-shaped obstacle surfaces and boundary effects on obstacle surfaces with different acoustic properties, the effect of the powder material dispersivity on the structural characteristics of compacts near the obstacle surface, and the spherical particle deformation (i.e., bronze) are examined in detail. The concept of the "cold" boundary zone recorded experimentally by Kusubov, Nesterenko, et al and its origins are discussed. It is noted that in mathematical modeling of the cold boundary zone, the deformation ridge amplitude forming on the obstacle surface rather than the particle size is the characteristic parameter. The cold and hot zone formation is due to the characteristics of two-dimensional flows near the interface while the physical origin of the hot zones is similar to that of central zones forming under shock compaction of cylindrical porous bodies; the appearance of hot zones is observed only in the cases where the load propagation velocity on the obstacle surface is less than that of the plastic shock wave in the obstacle material due to the impulse effect of the obstacle on the powder material caused by the plastic deformation ridge. The authors are grateful to A.S. Starostin for help with the experiment and to V.M. Fomin and V.F. Nesterenko for discussing the findings. Figures 5; references 17: 11 Russian, 6 Western.

Nonsymmetric Rigid Rotor Dynamics in Bearings With Rotating Flexible Elements

927F0221A Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 92 pp 19-24

[Article by Ye.L. Golub, M.I. Pavlinov, Minsk; UDC 534.011]

[Abstract] A perfectly rigid (with respect to bending, torsion, and tension-compression) vertical rotor of a given mass spinning at a constant angular velocity and supported by two bearings located at a specified distance from each other whereby the lower and upper bearings are separated from the center of mass by a different distance is considered. The supports contain unsymmetrical flexible elements rotating in sync with the rotor which makes small vibrations; the measure of the transverse and angular components of its vibrations are defined. The problem of this rotor's dynamics is formulated and its equation of motion in the case under study is derived. The conditions under which the transverse and angular vibrations are independent from each other are formulated and the characteristic equation which corresponds to a system of differential equations of angular momentum and momentum for a perfectly balanced rotor is derived. The effect of the lack of bearing rigidity on the motion stability, the effect of damping in bearings on the motion stability, and the case of induced vibrations are considered. It is shown that in a number of cases the rotor vibration instability related to its nonsymmetry may be corrected due to the nonsymmetry of the bearings in the presence of sufficient damping. An

analysis of induced vibrations reveals that at a sufficiently high angular velocity, the rotor has the property of self-centering. Tables 1; references 5: 4 Russian, 1 Western.

On Folded Shell Analysis

927F0221C Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 92 pp 105-114

[Article by V.A. Pukhliy, V.I. Shalashilin, Moscow; UDC 539.3]

[Abstract] A folded shell (rectangular in projection upon a plane) with a step function with discontinuities at corner points is examined in a Cartesian system of coordinates connected by a given relationship. Equations for such a plicated shell are derived in a coordinate form which is characterized in that the transition to coordinate-wise forces and loads makes it possible to avoid the need to formulate the force and displacement conjugation at corner points. The boundary value conditions are formulated on the basis of traditional notations after transforming them from traditional displacements and forces to coordinate-wise. For illustration, taut strained state of a hollow gas turbine blade which is represented as a closed cylindrical shell with a noncircular contour is considered. The boundary value problem described by a system of equations and finite relations and boundary value conditions is solved analytically using the method of integral relations and the modified method of successive approximations; to accelerate its convergence, Lanczos's telescopic exponential series shift method is used. A Fortran routine and an algorithm developed for analyzing the problem are cited. Figures 6; references 7.

On Torsion of Cylindrical Composite Shaft of Finite Length

927F0221B Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 92 pp 58-66

[Article by D.Ya. Bardzokas, A.L. Kalamkarov, O.B. Rudakova, Athens and Moscow; UDC 539.3]

[Abstract] The difficulty of solving the problems of mechanics of highly inhomogeneous composite materials due to the fact that the coefficient of the corresponding differential equations are rapidly changing functions of spatial coordinates is addressed and the problem of torsion of a multilayer composite hollow cylindrical shaft of a finite length is investigated. The problem is formulated assuming that the shaft consists of N cylindrical layers of an identical small thickness whereby the material inside each layer is characterized by certain inhomogeneity while the structure of all layers is identical. Using Uflyand's procedure and the averaging method, a generalized integral transform is performed and then used to derive an analytical solution. This solution is versatile with respect to selecting the type of the function which determines the inhomogeneity structure inside each recurrent layer. This function may be piecewise-constant. In the limiting case of homogeneous material and constant equation coefficients, the generalized integral representation is reduced to known transformations used by Arutyunyan, Abramyan, et al. A numerical example is cited. Figures 3; references 8: 7 Russian, 1 Western.

Elastoplastic Shell Bending Under Complex Loading

927F0221D Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 92 pp 115-118

[Article by K.I. Bon, North Korea; UDC 539.3]

[Abstract] Bending of elastoplastic shallow shells under complex loading is considered by the variational method. To this end, the time interval is broken up into n equal parts and the problem is reduced step by step to solving a system of equations at each iteration using the cylindrical shell rigidity, bending rate, shell thickness, stress rate function, shear modulus, transverse loading rate, and the shell's principal radii of curvature as independent variables. The boundary value conditions are defined and the boundary value problem is formulated by the Bubnov-Galerkin method. The system of boundary condition equations is nonlinear and algebraic relative to the unknown parameter and is solved by the successive approximation method. The Bubnov-Galerkin process convergence is tested and it is shown that the process converges, at least for a plate. The conclusion is drawn that the process convergence for a shell can be easily demonstrated. References 6.

On Steady-State Motion of Shallow Spherical Flexible Shell in Circular Orbit

927F0221E Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 92 pp 119-124

[Article by I.I. Karpov, Moscow; UDC 531.35]

[Abstract] The effect of elastic vibrations and internal strain in a large elastic structure on its motion as a whole relative to the center of mass is considered and the structure is simulated by a hollow elastic spherical thin shell. The shell motion is considered in a central Newtonian gravity field in a circular orbit. The shell is assumed to be an isotropic uniform body performing only longitudinal vibrations along the axis of symmetry, i.e., elastic deformations in a direction perpendicular to the symmetry axis are small compared to those parallel to the symmetry axis. The internal friction forces developing under elastic vibrations are described with the help of a dissipative Rayleigh function. Differential equations of the shell's center of inertia motion in a circular orbit which represent the shell motion as a whole

and deformations of its individual elements are derived in the framework of the elasticity theory. The quasistatic motion conditions are considered and the existence of a steady-state shell spinning around the symmetry axis perpendicular to the orbital plane is established. This spinning stability is examined in the quasistatic condition and it is demonstrated that internal damping leads to a principal change in the type of stability. Figures 1; references 10: 9 Russian, 1 Western.

On Stabilizing Effect of Geometrical and Stiffness Parameters on Flutter of Panels With Lumped Masses in Supersonic Flow

927F0221F Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 92 pp 144-152

[Article by L.M. Zoriy, N.I. Sorokatyy, Lvov; UDC 533.6:013.42]

[Abstract] The issues of vibrations and stability of flexible panels with a finite number of degrees of freedom and distributed parameters are addressed using the method of characteristic series assuming that the variable can be fully separated and the piston theory can be used. The problem of the stabilizing effect of geometrical and stiffness parameters on the flutter of a panel with lumped masses on one side and a supersonic flow on the other side is formulated and the characteristic equation is derived assuming that the panel's extent across the flow is sufficiently large compared to its span. Small panel vibrations and the panel stability with a single oscillator, the panel stability with two concentrated masses, and a rectangular panel with a mass lumped in the rectilinear segment are analyzed in detail. The conclusion is drawn that a massless panel with a mass—the oscillator—lumped on a segment of a straight line cannot lose stability and that the flow direction reversal does not affect the panel vibrations and stability. It is noted that such a conclusion can be easily derived for a similar problem of the flutter of a three-layered cylindrical shell. Figure 5; references 11.

Mathematical Modeling of Multipanel Solar Battery Deployment Dynamics

927F0221G Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 92 pp 177-179

[Article by V.I. Panichkin, Moscow; UDC 624.07:534.1]

[Abstract] Many of today's space exploration tasks call for using in space multipanel solar batteries which can be deployed either forcibly by an electric drive or due to the potential energy stored in various types of springs. Consequently, the planar motion of a succession of hinged perfectly rigid rods which simulate the frames of solar panels which are deployed into a straight line by a spring-and-cable mechanism with rollers located on the hinge shafts is investigated. In other words, a multipanel solar battery (SB) deployed by the force developed by a spring is considered and a system of second-order differential equations is derived and solved by the finite difference method. An algorithm and a routine developed in the PL-1 language for computer analysis of the 130° deployment of a four-panel solar battery with various combinations of roller dimensions are described. Optimal deployment mechanism parameters are recommended. Figures 4; references 3: 2 Russian, 1 Western.

Effect of Plastic Deformations on Elastic Properties of Metals

927F0221H Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 92 pp 184-189

[Article by A.M. Zhukov, Moscow; UDC 539.374]

[Abstract] The behavior of elastic properties of metals under plastic deformation is examined in tubular aluminum samples whereby a circumferential deformation of about 2% is developed in each sample. After relieving the load completely and measuring the samples, they are subjected to biaxial tension along an adjacent ray. The wall thickness is measured by a gauge and Martens's optical-mechanical instrument. Neutral loading curves of the samples is plotted using the load relief method under tension and torsion conditions using tubular samples of steel 45 annealed at a 900°C temperature. Each sample is also deformed by pure tension by about 2%, then the load is relieved completely, the new transverse dimensions are measured, and the sample is again loaded in tension with torsion along straight lines. An analysis of the samples' plastic deformation shows that it substantially alters the elastic properties of the metal while neutral loading curves remain smooth for Al and steel 45 for various tolerance conditions. Experiments are also conducted with steel 30KhGSA and 1Kh18N9T. An analysis of the findings indicates that plastic deformation greatly affects the elastic properties of metals and shows that neutral loading curves should be plotted by the total load relief method with subsequent loading under proportional load variations. In this case the metal creep is eliminated and the variability of elastic properties is automatically taken into account. Figures 4; tables 2; references 13: 11 Russian, 2 Western.

Robotized Complexes and Machine Tool Modules for Processing Not Rotatable Blank Parts

927F0099A Moscow MASHINOSTROYENIYE in Russian No 12, Dec 91 pp 3-8

[Article by A.V. Zagurskiy, candidate of technical sciences, and V.I. Zagurskiy, candidate of technical sciences; UDC 658.52.011.56.012.3, 621.865.8, 621.9.06]

[Abstract] Several robotized technological complexes for machining blank parts which are not solids of revolution but rather have flat surfaces and polygonal cross-sections are described, such complexes being difficult to lay out and set up. Two such complexes each include a model MP-9S industrial robot but different milling machines, one a special-purpose model 6R80 horizontal milling machine and one a modified general-purpose model 6R81G milling machine with a hydraulic rather than mechanical drive. Two other such complexes each include a model LF-260 milling machine tool turret but different industrial robots, one "Tsiklon-5" industrial robot and one a model UM-1 industrial robot. They are drilling machine tools operated by robots, vertical drilling machine tools such as model 2R135F2 with numeric program control operated by a model PR-10I industrial robot, a model 1M112 bench-mounted drilling machine tools operated by a model 4-3 industrial robot. There are reaming and threading machine tools operated by model MP-9S, Pr5-2E, or pneumatically driven "Brig-02A" industrial robots. Technological complexes with industrial robots and flexible production modules have been installed in the Stryy Forging and Pressing Plant, in the Kherson combine (model 2754VOS9777K complex having been designed at the Odessa Special Engineering Office for diamond-tool lathes), in the Ural Coach Manufacturing Plant (model "Tsiklon-3B"), and in the plant of the Industrial Association "Rostov Sanitary Engineering". Several other multipurpose and precision machine tools for robotized technological complexes are being built at the Odessa Machine Tool Manufacturing Plant. Figures 9; tables 1.

Matrix Equations of Motion for Nonholonomic Systems

927F0104A Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 321 No 3, 1991 (manuscript received 27 Sep 91) pp 499-504

[Article by V.V. Velichenko, Institute of Machine Design imeni A.A. Blagonravov, USSR Academy of Sciences, Moscow; UDC 519.7]

[Abstract] Two basic kinds of differential equations describing motion of nonholonomic mechanical systems are derived in a matrix form convenient for solution by computer with use of symbolic language. They are derived essentially from equations of motion for holonomic mechanical systems, these equations transforming as the constraints are replaced with nonholonomic ones. A holonomic system free of nonholonomic constraints is described by the system of differential equations $M(q,t)d^2q/dt^2 = f(q,dq/dt,t)$, where q is the vector of its generalized coordinates, M is an nXn-dimensional symmetric nondegenerate matrix, and f is an n-dimensional vector which combines all terms not associated with acceleration d^2q/dt^2 including those associated with external acting on the system. On this system are then imposed nonholonomic constraints of the general form $J(q,dq/dt,t) = 0$, where J is an m-dimensional continuous and continuously differentiable with respect to its arguments vector-function ($m \leq n$). The geometrical tool for analysis and solution of this system of equations is a Cartesian coordinate space Q of q-vectors, at each point of that space being constructed a configuration manifold V of velocities dq/dt at fixed q and t. To this description of nonholonomic constraints $J(q,dq/dt,t) = 0$ is added a parametric description of the configuration manifold $dq/dt = \gamma(q,v,t)$, where v is an (n-m)-dimensional vector of parameters: curvilinear coordinates in manifold V. The equations for the nonholonomically constrained system are then put in the matrix form $Md^2q/dt^2 = f + \rho$, where ρ is an n- dimensional vector of reactions of constraints. Two theorems are proved, with the aid of three lemmas, regarding description of a nonholonomically constrained system by (n-m)-parametric sets of solutions to the equations for this system without nonholonomic constraints in generalized coordinates. As two specific problems are considered first the equations of motion for a homogeneous sphere on a rough horizontal surface, the Lagrange function for the free sphere driven only by inertia being $L = T = m2$ (dot x^2 + dot y^2) + J2 (dot ψ^2 + dot φ^2 + dot θ^2 + 2 dotψ dotδ cosθ), and then the dynamics of controllable motion under nonlinear nonholonomic constraints. The article was presented by Academician K.V. Frolov on 5 August 1991. References 5.